The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association
Western Orthopedic Association

JULY 1960

American Volume
Vol. 42-A, No. 5

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
82 PORTLAND PLACE, LONDON, W. 1, ENGLAND

The Journal of Bone and Joint Surgery

PUBLISHED IN TWO VOLUMES

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Published in the United Kingdom for The British Editorial Society of Bone & Joint Surgery by E. & S. Livingstone, Teviot Place, Edinburgh

THE JOURNAL OF BONE AND JOINT SURGERY

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The Journal of Bone and Joint Surgery (American Volume) is issued eight times a year—in January, March, April, June, July, September, October, and December. The 1960 subscription price, payable in advance, is $14.50. Single copies $3.00.

The Journal of Bone and Joint Surgery, second-class postage paid at Boston, Mass. and at additional mailing offices. Editorial and business offices, 8 The Fenway, Boston, Mass. Accepted at the special rate of postage provided for in the act of February 28, 1925. Paragraph 4, Section 412, Postal Laws and Regulations; authorized April 21, 1932. Additional entry at Concord, New Hampshire, authorized June 10, 1947.

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British Volume, $7.50
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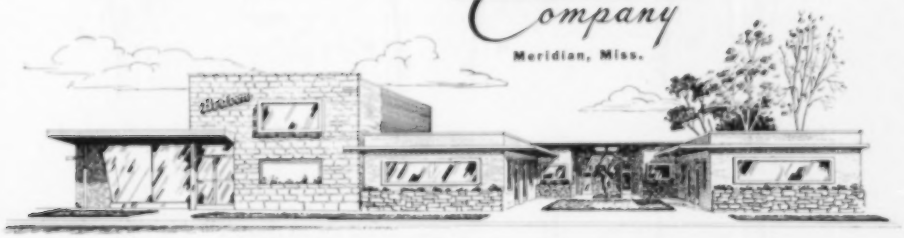

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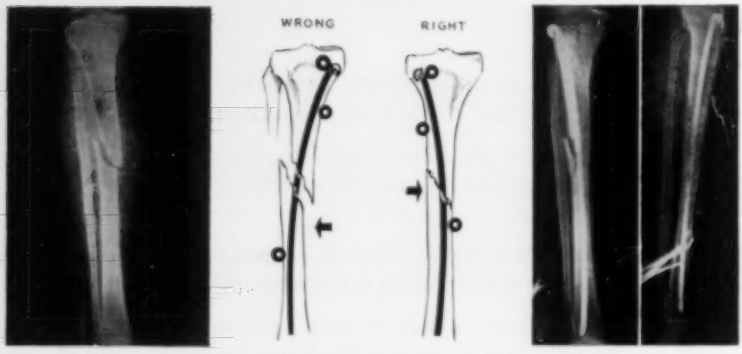
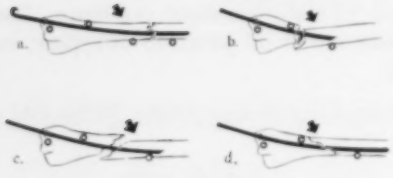


Direction of pin insertion determines compression or distraction.



V (victory) = Good Compression

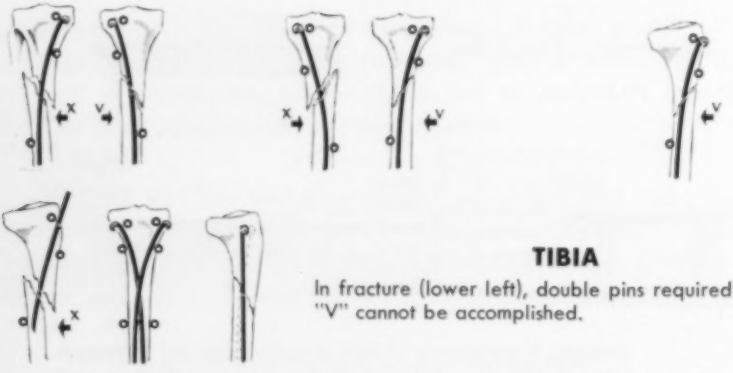
X (no good) = Distraction

RADIUS

Length of fragment and direction of fracture line determine angle of pin insertion.

RULE

Axis of pin should be same direction as axis of fracture line, intersecting to make a "V" instead of an "X".



TIBIA

In fracture (lower left), double pins required because "V" cannot be accomplished.

* Rush, Leslie V.; Fracture Problems, Mississippi Doctor, Vol. 36, No. 10, March 1959.

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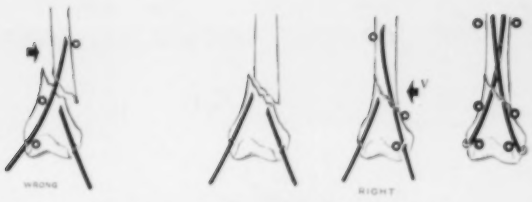


LOWER FEMUR

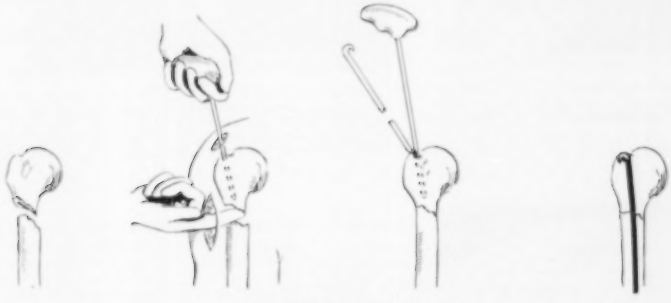
Double pins required. Introduce most effective pin first.

UPPER FEMUR

Dependent upon direction of fracture line, special type pin might be indicated.

HUMERUS, BELOW DELTOID

Requires precise handling for good healing. For fracture at right use large curved pin for compression.



UPPER THIRD

To avoid angulation, insert pin axially in short fragment.

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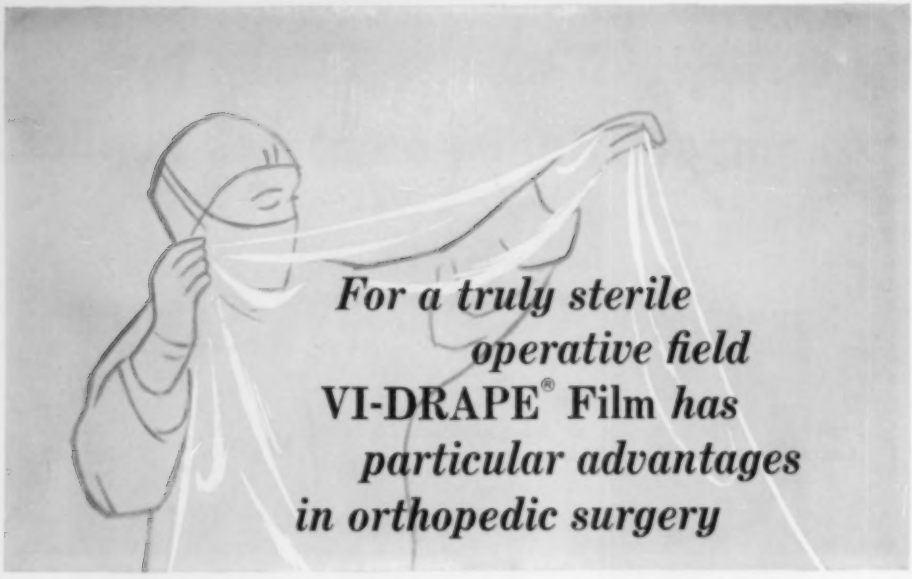

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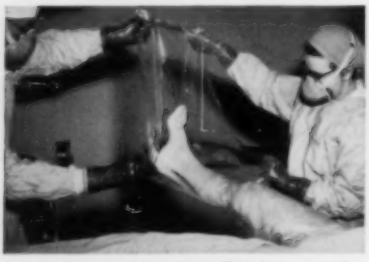

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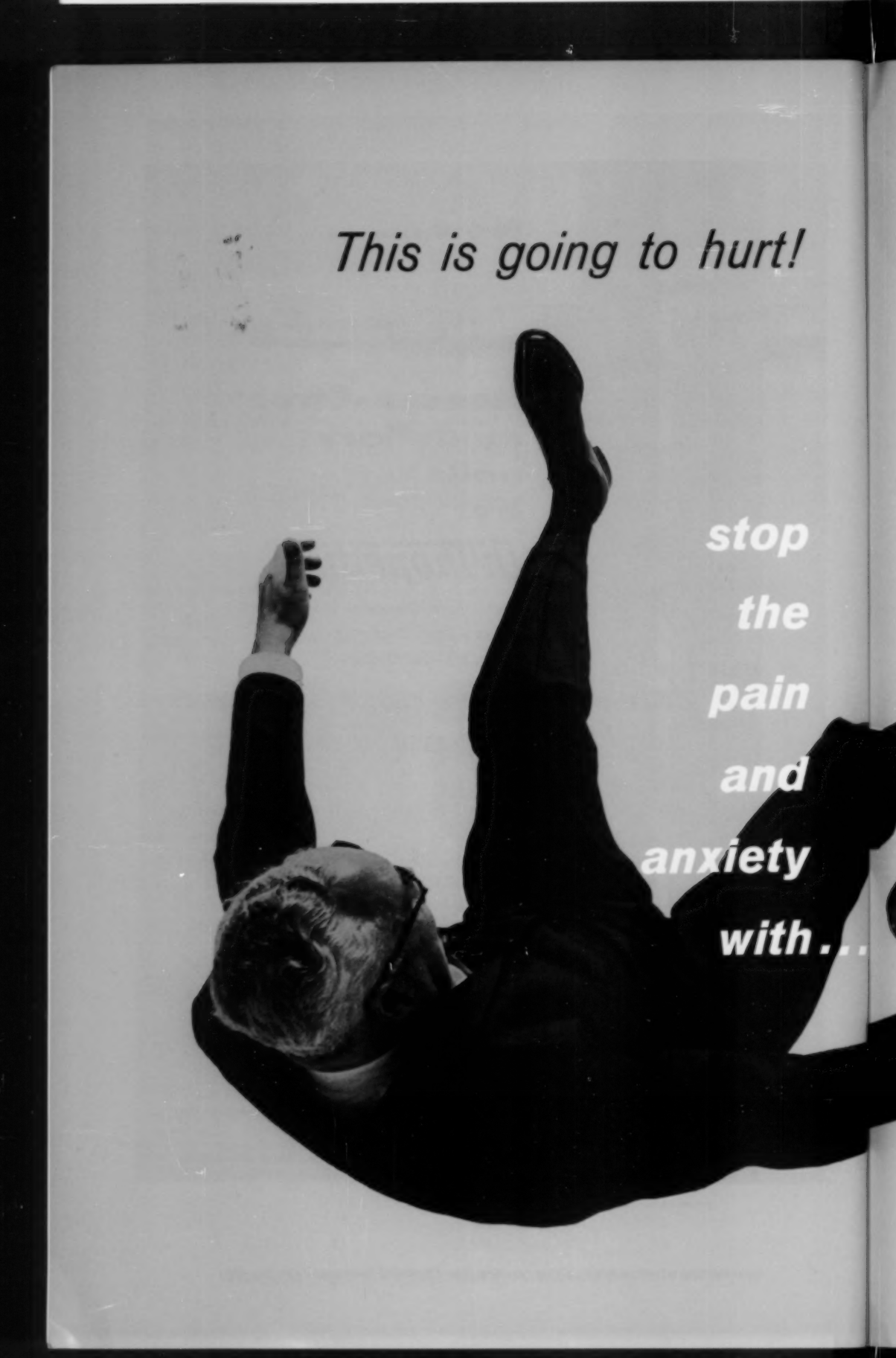
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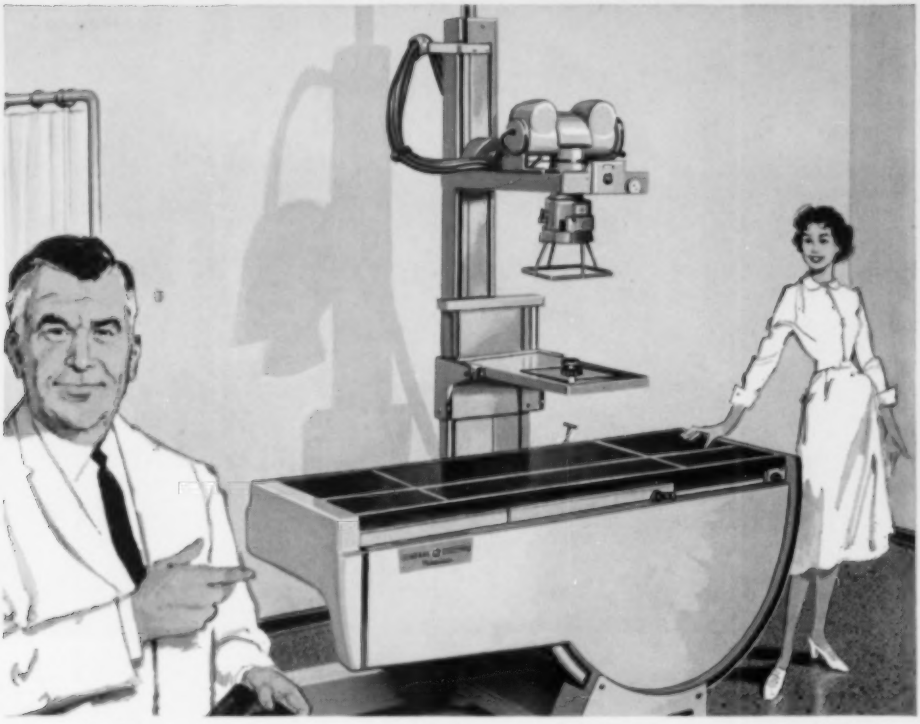

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(Left) Severe arthritic involvement of both hips in 64-year-old white male. (Right) Bilateral insertion of Moore Vitallium Self-locking Hip Prostheses restores patient's walking ability.

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REFERENCES: 1. Matchett, F.: Rocky Mountain M. J. 56:47, 1959. 2. Mahoney, J. W. et al.: Am. J. Surg. 95:577, 1958. 3. Breck, L. W.: Southwestern Med. 35:207, 1954. 4. Savastano, A. A. et al.: Rhode Island M. J. 41:425, 1958. 5. Ghormley, R. K.: Rocky Mountain M. J. 54:337, 1957. 6. Barker, W. E.: Manitoba Med. Rev. 38:673, 1958. 7. Symposium on Femoral Head Replacement Prostheses, J. Bone & Joint Surg. 38A:407, 1956. 8. Thompson, J. E. M.: Surg. Gynec. & Obst. 96:301, 1953. 9. Bohlman, M. R.: Am. J. Surg. 84:268, 1952. 10. Bascom, J. et al.: J.A.M.A. 169:1863, 1959. 11. Coventry, M. B.: Surg. Gynec. & Obst. 109:243, 1959. 12. Thompson, F. R.: New York State J. Med. 52:3011, 1952. 13. Moore, A. T.: J. Bone & Joint Surg. 39A:811, 1957. 14. Thompson, F. R.: In Acad. Orthop. Surg. Instructional Course Lectures, vol. 16, C. V. Mosby, 1959, p. 299. 15. Moore, A. T.: In Acad. Orthop. Surg. Instructional Course Lectures, vol. 16, C. V. Mosby, 1959, p. 309. 16. Thompson, F. R.: J. Bone & Joint Surg. 36A:389, 1954. 17. Stinchfield, F. E., et al.: J. Bone & Joint Surg. 39A:1043, 1957. 18. Peterson, L. T. and Raad, M. A.: Med. Ann. D. C. 24:233, 1955. 19. Gaenslen, F. G.: Wisconsin Med. J. 59:181, 1960. 20. Hart, G. M.: J. Lancet 78:369, 1958. 21. Carlander, L. W.: Minnesota Med. 42:566, 1959. 22. Beegel, P. M.: J. Maine M. A. 49:86, 1958. 23. Moore, A. T.: South. M. J. 45:1015, 1952. 24. Day, P. L. and Hinchey, J. J.: Clin. Orthop., No. 6, p. 27, 1955.

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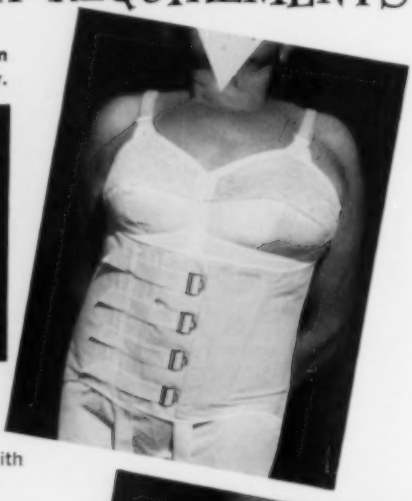

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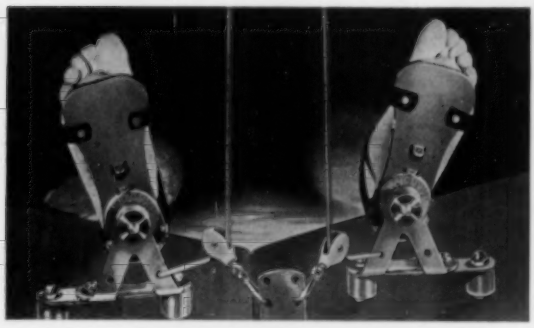

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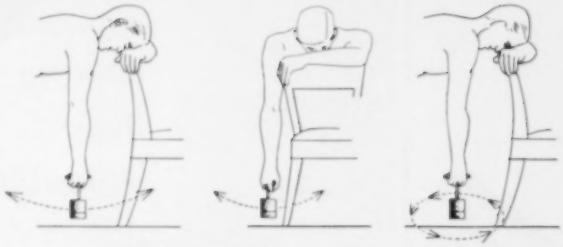

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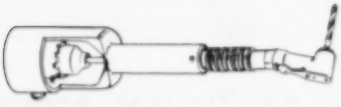

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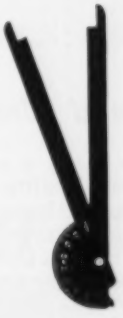

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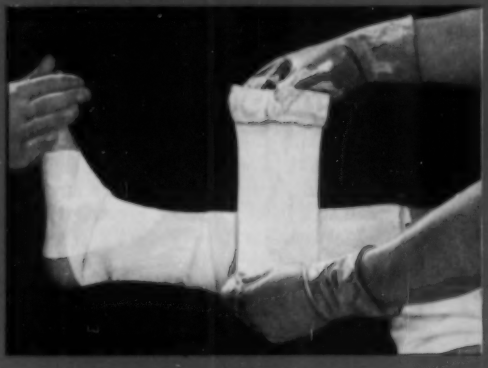

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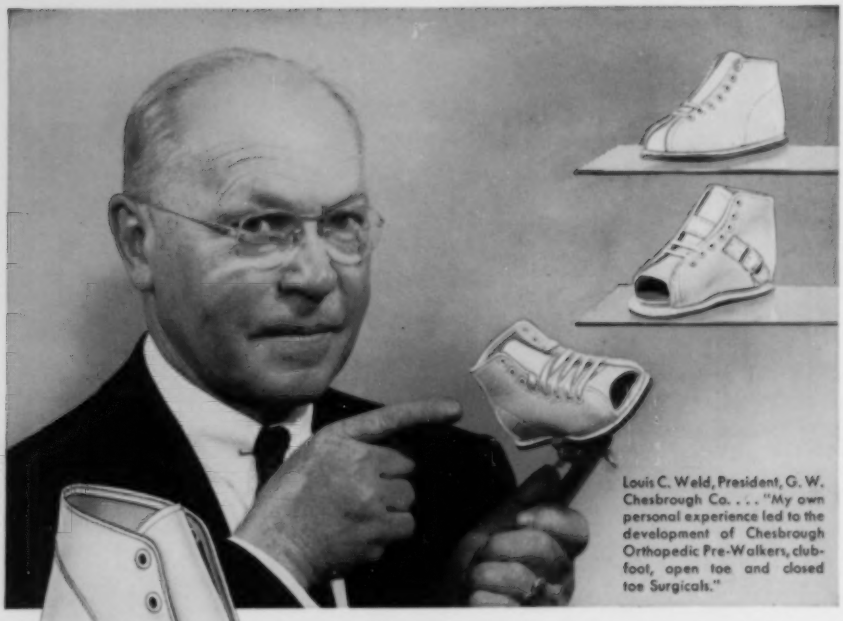

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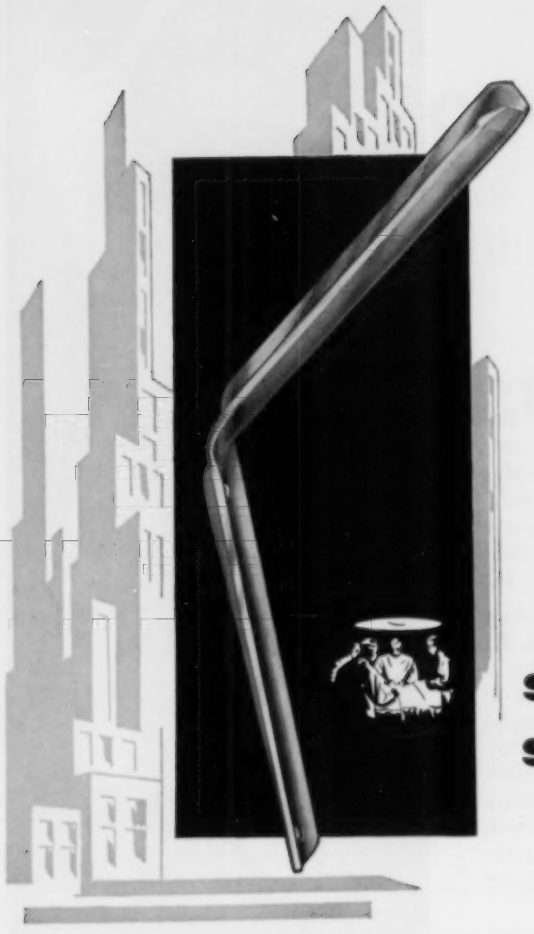

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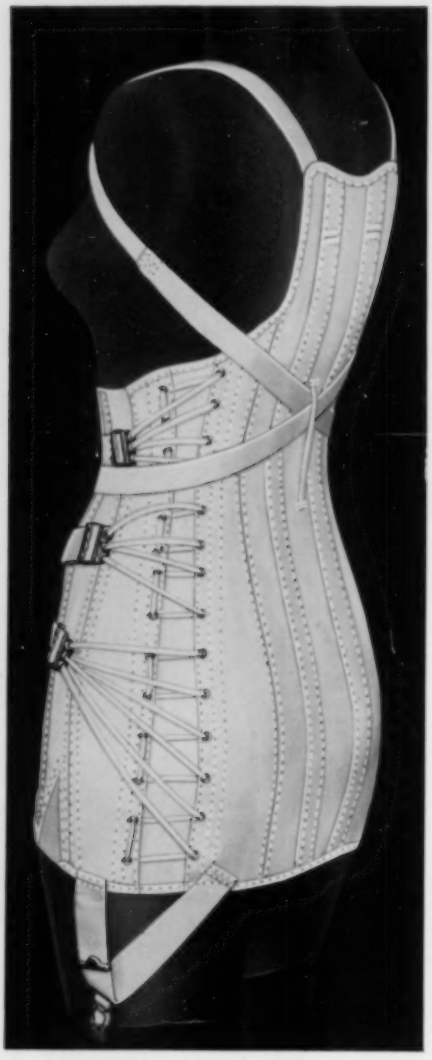

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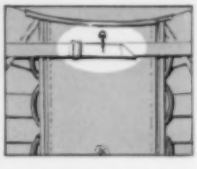

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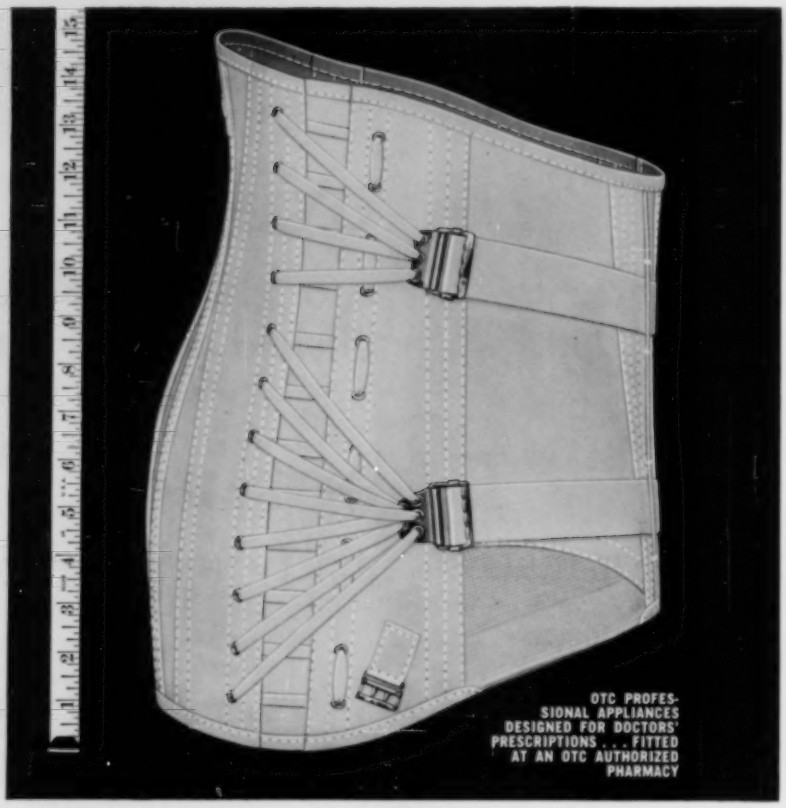

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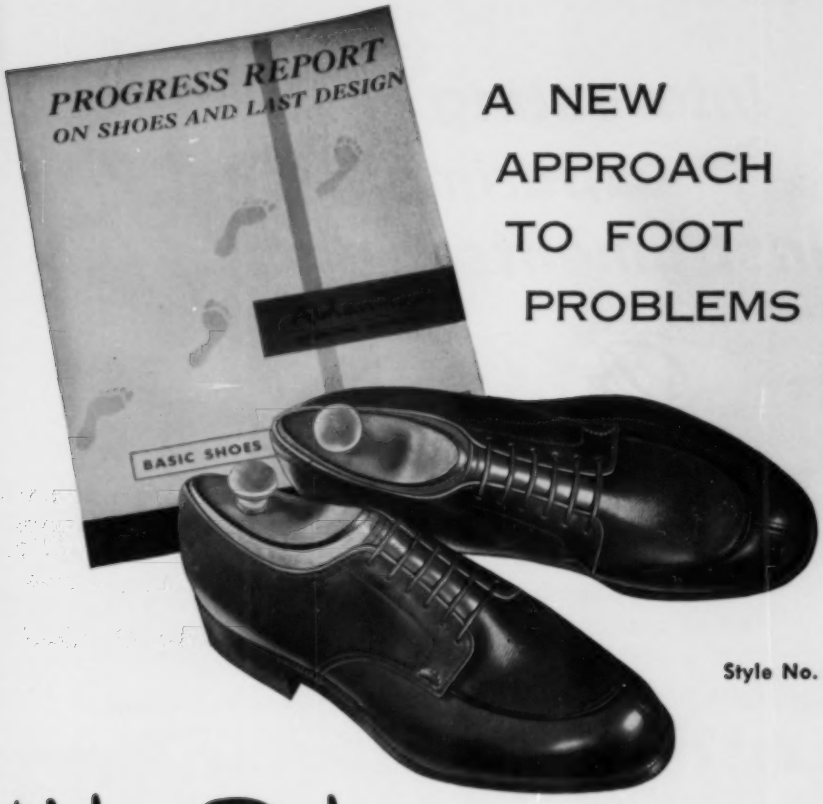

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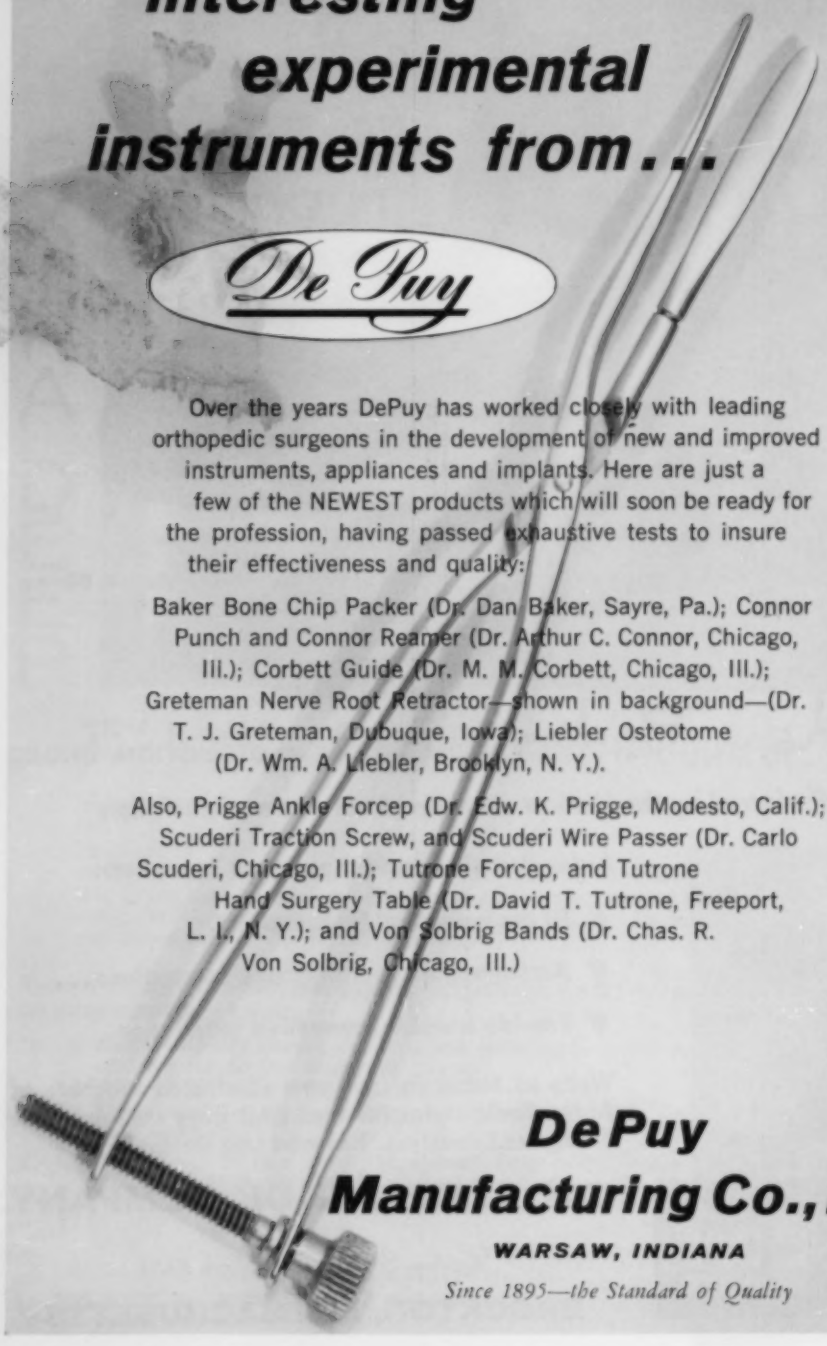

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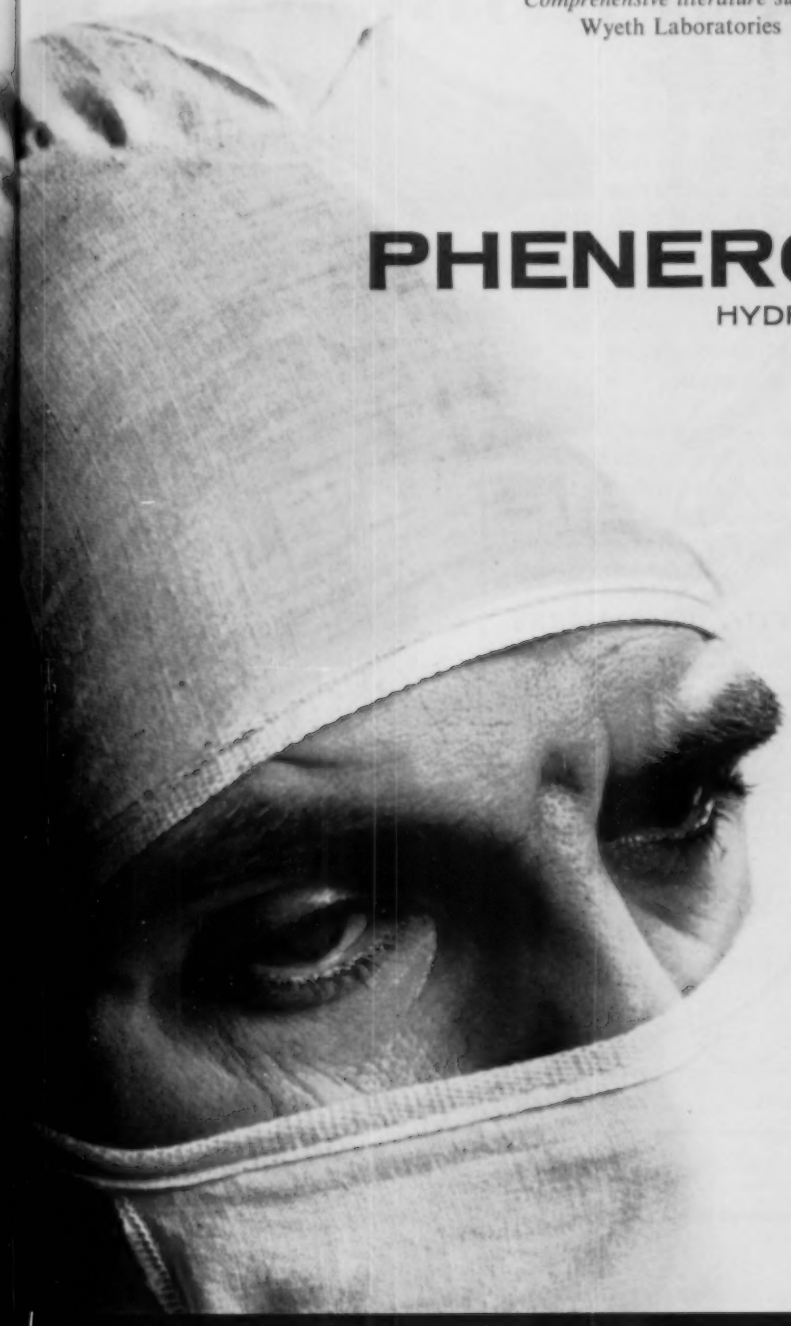

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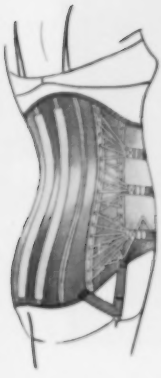

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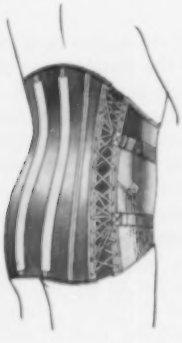

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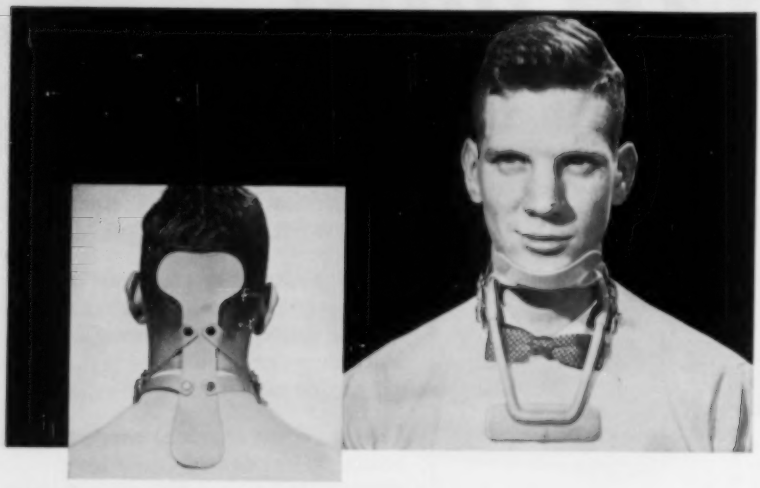

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[1]From Jackson, R.: The Cervical Syndrome, 2nd Ed., Springfield, Ill., Courtesy of Charles C. Thomas, Publisher, July, 1958, Pg. 155.

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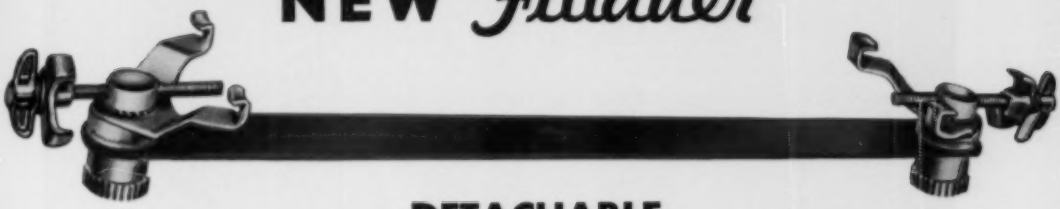

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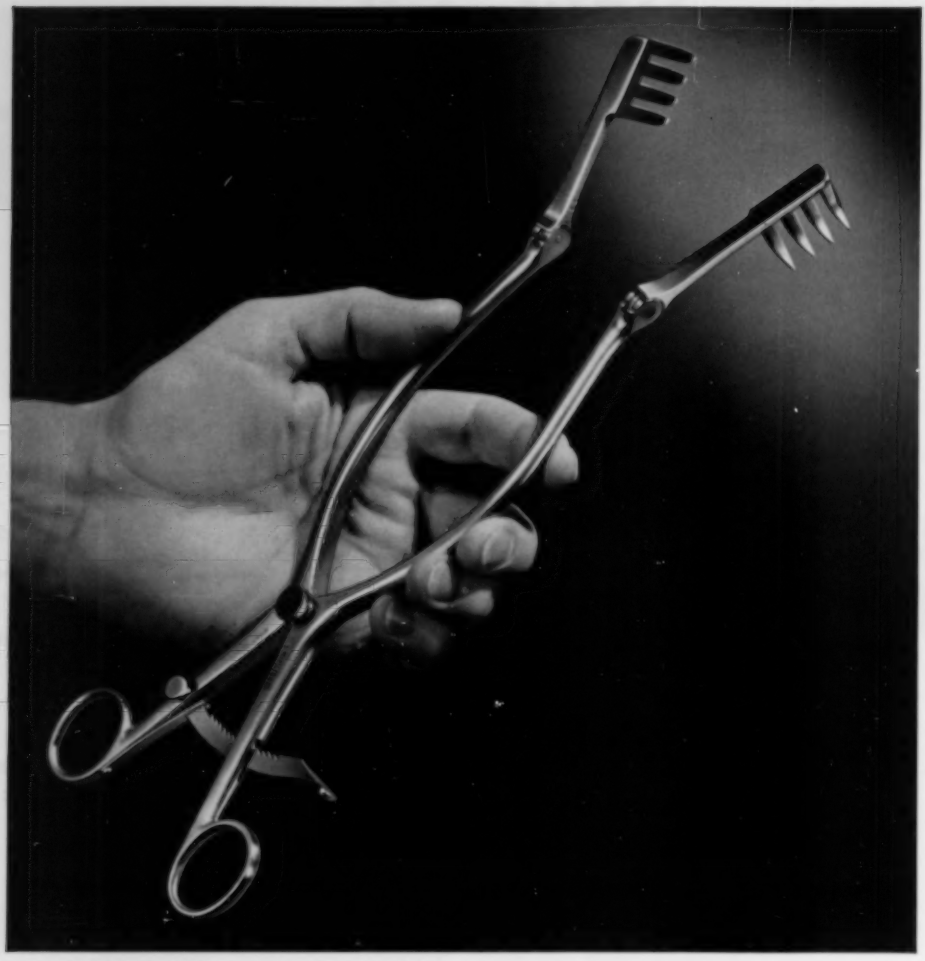

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Experimental Immobilization and Remobilization of Rat Knee Joints*

BY E. BURKE EVANS, M.D., G.W.N. EGGERS, M.D., JAMES K. BUTLER, M.A., AND JOHANNA BLUMEL, PH.D., GALVESTON, TEXAS

From The Department of Surgery, Orthopaedic Division, University of Texas Medical Branch, Galveston

Experimental immobilization of joints has been carried out by numerous investigators [4,10-17,19,20], beginning with Menzel in 1871, and the morphological changes accompanying immobilization have been rather well established. So far as we can ascertain, however, no attempt has been made to study the effect of remobilization of previously immobilized joints on an experimental basis. It was the purpose of this experimentation to determine the nature of changes occurring as a result of joint immobilization in a small laboratory animal and to show the degree of reversibility of these changes with remobilization.

PROCEDURE

Immobilization

Mature Sprague-Dawley male rats housed individually and weighing 300 grams or more were used. Previous investigators employed either rabbits or dogs. We selected the rat because of ease of maintenance of large numbers and because the knee joints of these animals are small enough to make serial histological sectioning feasible. In addition, the knee joint of the rat is similar enough to that of the human being to make orientation easy. The principal differences are in the ossified menisci and the habitual flexed position.

Immobilization in partial flexion was maintained by an internal plexiglass splint secured on the lateral aspects of the femur and tibia with steel pins through corresponding drill holes in the splint and bones (Fig. 1). The splint was passed through the muscles of the thigh and leg, and thus only its distal tip was palpable beneath the skin. This method of fixation was chosen after numerous trials and failures with other devices, including plaster casts. Because the degree of flexion of the knee was not marked, and the knee of the rat usually functions in flexion, these animals with the hip and ankle free could bear weight on the immobilized extremity with little difficulty.

The left knees of these animals were immobilized for periods of fifteen, thirty, forty-five, sixty, or ninety days; the right knees served as controls. For each major group of animals there was one control animal in which only pins were placed in the tibia and femur.

* This investigation was supported by Research Grant No. A 848 (C-1, 2, and 3) from the National Institute of Arthritis and Metabolic Diseases, United States Public Health Service.

It was readily apparent when the device was applied that rigid fixation could not be obtained and that, certainly, in our animals there would be some motion after a few days in every instance, regardless of the quality of fixation at the time of operation due to erosion and absorption of bone at the pin sites. Thus, we undertook initially to grade the fixation both at the time of operation and at the time of sacrifice as I, II, III, and IV, the numerals corresponding to the number of millimeters of passive motion obtainable in the knee as measured from the hip to ankle. Attempts to correlate the findings in the knee joint with the grade of fixation showed that the grading was meaningless. It became evident that as long as the fixing device was in place the limitation of motion was adequate to produce joint changes that were impressively similar from animal to animal within each group. Grading of the fixation was then abandoned.

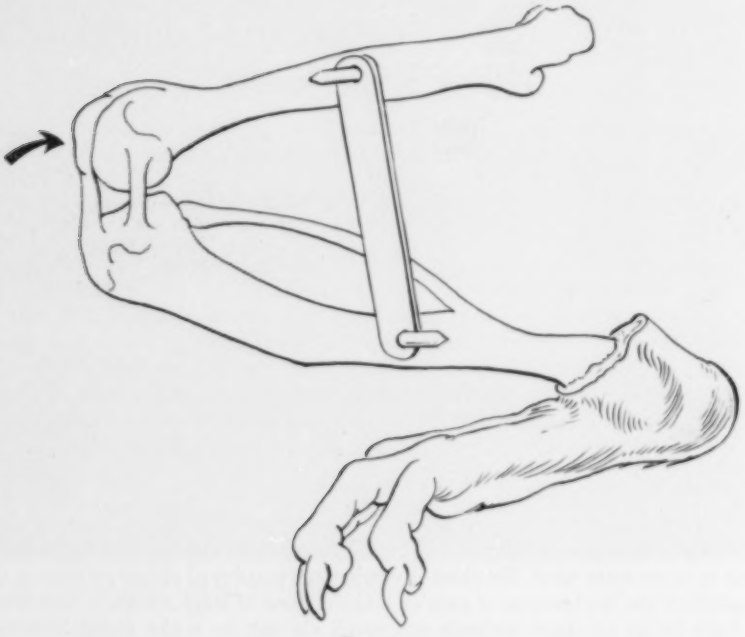

FIG. 1

The diagram shows the position of the internal plastic splint and the method of pin fixation. The arrow indicates the area of pressure between the patella and the femoral condyle.

Remobilization

Remobilization of the joints was accomplished according to three procedures: abrupt forced movement; gradual passive movement; and pure active movement. The periods of remobilization varied from thirty-five to fifty days, except for two animals that were sacrificed five and fifteen minutes after forced remobilization and two others that were sacrificed after seven days of active remobilization. All the remobilized animals had been previously immobilized for forty-five or 110 days.

In the group with abrupt forced remobilization, the knees were moved abruptly through a full range of extension and flexion immediately after removal of the splint. The animals were then allowed free motion, but no further manipulation was carried out prior to the date of sacrifice. In the group with gradual passive movement the joints were moved without force through the full allowable range of motion at the time of splint removal and through a full range of available

motion ten times once each day thereafter until sacrifice. The animals in the group with only active motion were allowed free activity without manipulation of any sort after removal of the splint. These animals were taken out of the cages frequently and allowed to move about to encourage use of the extremity.

At the time of sacrifice the effectiveness of remobilization was determined by direct measurement of the range of passive motion of the knee and by comparison of this motion with that of the opposite, control extremity.

Sectioning

The method of preparing and sectioning of the histological material was described in a previous publication[1]. Suffice it to state that after fixation and decalcification, the extremities were trimmed so that only four or five millimeters of the femoral and tibial shafts remained with the joint. Before embedding of the tissue in paraffin, the joint space was opened on the lateral side by cutting of the block of tissue in the sagittal plane. Sectioning was done in the sagittal plane only, proceeding from the lateral to the medial side. Only joints from which adequate serial sections were obtained were used for interpretation and included in the final count.

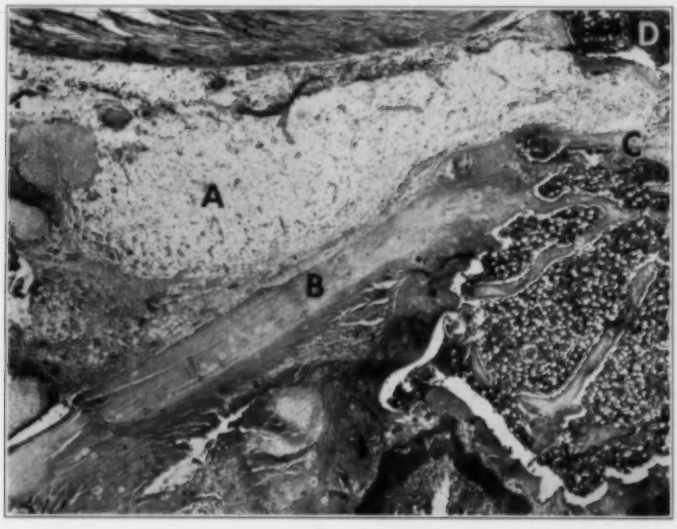

FIG. 2

Immobilization for thirty days. Note the complete filling of the central area (*A*) of the joint by connective tissue that adheres to the posterior cruciate ligament (*B*) and to adjacent portions of the femoral condyle (*C*) and patella (*D*) (× 25). See Fig. 15 for orientation.

OBSERVATIONS AFTER IMMOBILIZATION

Of the total of thirty-nine animals, three were immobilized for fifteen days, five for thirty days, six for forty-five days, twelve for sixty days, and ten for ninety days. Two additional animals immobilized for sixty days were used for the study of the gross morphology.

Gross Findings

After application of the splint, progressive muscle atrophy was observed for the first ten days to two weeks; subsequently, there was some restoration of muscle bulk.

Gross examination of the joints of the two animals that had been immobilized for sixty days was carried out immediately after sacrifice. In each of the immobi-

FIG. 3

Immobilization for sixty days. Section through the medial condyle. Note the proliferation of connective tissue within the joint space, the adhesions to the surface of the condyle that is not apposed to another joint surface, and the tongue of connective tissue projecting between the femoral condyle (*A*) and the meniscus (*B*) (× 25).

lized joints the intercondylar notch was filled with fatty connective tissue, processes of which adhered to the femoral condyles around the notch and enveloped the cruciate ligaments and the tibial condyles. The infrapatellar pad of fat was thickened. The cartilage of the femoral condyles was lusterless and had a bluish tinge that deepened centrally and was especially marked on the medial condyle. No lesion was observed in the articular cartilage. In the control joints, the intercondylar notch was free of connective tissue, the cruciate ligaments were visible, and the tibial condyles could be exposed with ease. The condylar cartilage was shiny and its color varied from white to light gray.

Microscopic Findings

These findings will be described in the order of their appearance to avoid repetition for each group of animals. We shall consider these findings separately as they were observed in (A) connective tissue and synovial membrane; (B) cartilage; and (C) bone.

A. Connective Tissue and Synovial Membrane

The earliest detectable histological change was proliferation of the subsynovial intracapsular connective tissue in the infrapatellar and intercondylar re-

Fig. 4: Immobilization for sixty days. There is loss of the tangential cartilage cells underlying this adhesion to the femoral condyle. At the right of the section the cells of the intermediate stratum are now at the surface and they appear to be partly enveloped by connective tissue (× 100).

Fig. 7: Immobilization for sixty days. The trabecula (*A*) bounding the subchondral lesion (*B*) shows irregular resorption on the surface in contact with the highly vascular connective tissue, whereas the surface in contact with the normal marrow space (*C*) remains intact (× 150).

Fig. 14: Immobilization for eleven days; thirty-five days after active remobilization was started. This cystic lesion of the femoral condyle contains loose avascular connective tissue and has a capsule composed of dense vascular fibrous tissue and remodeled osseous trabeculae. The opening to the joint space is partially filled with fibrous tissue (× 40).

Fig. 17: Normal vascular openings (*A* and *B*) extend from the subchondral marrow spaces into the radial cartilage. It is with such vascular channels that cartilage ulcers or clefts may connect (× 120).

Fig. 7

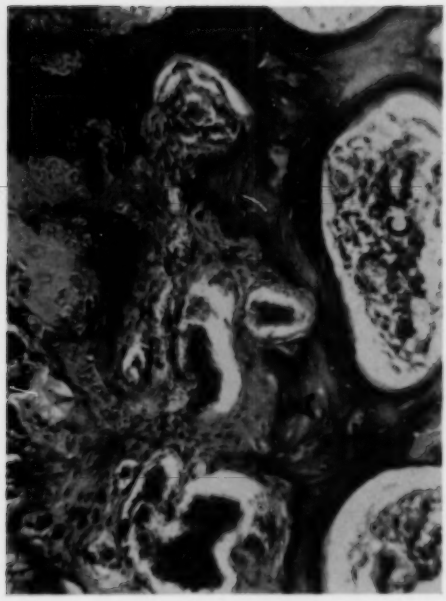

Fig. 17

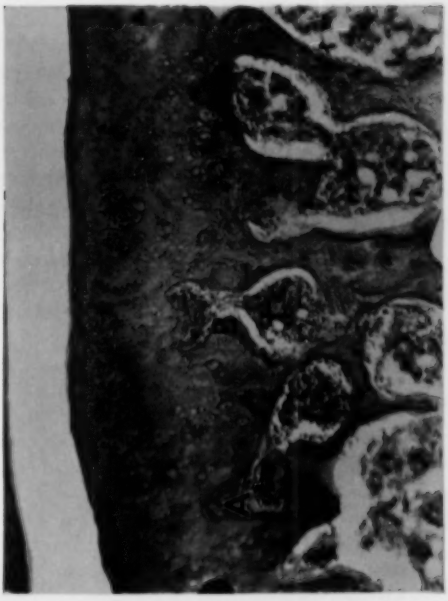

Fig. 4

Fig. 14

gions. Fatty connective tissue enveloped the cruciate ligaments and filled completely the intercondylar notch. The normal synovial cleft was obliterated, and the connective tissue appeared in the central part of the joint space as a continuous sheet extending posteriorly from the patellar tendon to the portions of the articular surfaces of the tibia and femur that were not in contact (Fig. 2). In the more lateral or medial sections of the joint, this connective tissue approximated the exposed femoral condyles on each side of the patella and was seen in some sections to project in the form of tongues of synovial membrane between one of the condyles and the patella or between one of the condyles and a meniscus (Fig. 3).

Connective-tissue proliferation was present in all three of the knees immobilized for fifteen days and it was well established at thirty days. After thirty days there was no obvious difference in the quality or extent of the connective tissue, although an inconstant finding was some suggestion of increasing density of the connective tissue after sixty days of immobilization.

As the connective-tissue proliferation advanced, some of the vessels in the infrapatellar and intercondylar regions were found occasionally to be engorged with blood. This vascular engorgement was particularly impressive in the knees immobilized for thirty days to sixty days, but after ninety days it was not a prominent feature.

Associated with the proliferation of connective tissue was the formation of adhesions to surfaces of the femoral condyles that were not apposed by the patella, tibia, or menisci. These adhesions occurred first around the cruciate ligaments and on non-articulating surfaces in the intercondylar region that normally have a fibrous synovial covering rather than a cartilaginous covering. The adhesions in these areas were evident at fifteen days. Definite adhesions to the unapposed articular cartilage were present at thirty days and were slightly more dense and more extensive at forty-five days; at sixty days (Fig. 3) they covered virtually every exposed surface. After sixty days, the character and extent of the adhesions did not appear to change.

B. Cartilage

Alteration in Unapposed Cartilage

Beneath the adhesions to the articular cartilage, the tangential layer of the hyaline cartilage was at first maintained, but, eventually, in certain areas, the surface of the cartilage lost its definition, and the cartilage appeared to be more or less confluent with the overlying connective tissue (Fig. 4). In the transitional zone of the articular cartilage the tangential cells were lost, and, in some areas, cells of the intermediate stratum appeared to be isolated from their supporting matrix and partially or completely surrounded by connective tissue. The tangential layer was still intact by as late as forty-five days, but by sixty days it had in many areas disappeared. The difference in appearance between the sixty-day and ninety-day adhesions was not striking.

The actual degree of thinning of cartilage was difficult to assess because of variation in the plane of sectioning; however, after sixty days of immobilization, comparison of sections from immobilized and control knees showed consistent evidence of thinning that could be ascribed to the loss of the more superficial cell layers, as seen in Figure 4. In the persisting deeper layers, the cells continued to appear viable, showing no alteration in shape, size, or staining quality. The thinning of the articular cartilage was most marked near the periphery of the femoral condyles, as, for example, around the margins of the intercondylar notch. Although the peripheral cartilage is normally thinner than that of the central condylar areas, it was this peripheral cartilage that was first covered with adhesions.

Alterations in Cartilage Apposed to Other Cartilage

There were three areas of cartilage-to-cartilage apposition in these knees:

tibial condyles to femoral condyles; femoral condyles to menisci; and femoral condyles to patella. The earliest change observed in these areas was found between the medial tibial and femoral condyles in a knee immobilized for thirty days (Fig. 5). In this area there was obvious compression of the cartilage with the chondrons of the superficial and intermediate strata appearing small and distorted. There was loss of homogeneity of the matrix, but there was no disturbance of surface fibers. Almost immediately peripheral to the area of pressure the cartilage was normal in appearance. This discrete area of compression was not observed in knees immobilized for longer than thirty days, and thus it is assumed that, with time, there was adaptation to or relaxation of the initial forces. After thirty days the areas of tibiofemoral contact showed no further alteration. Occasionally, a pannus-like tongue of synovial tissue was observed between the two condyles that adhered to one or the other of them.

Areas of contact between the femoral condyles and the menisci remained unaltered in all groups. The adhesions that did form between the two surfaces in several of the animals of the groups immobilized longer were more tenuous than those encountered in the central portion of the joint.

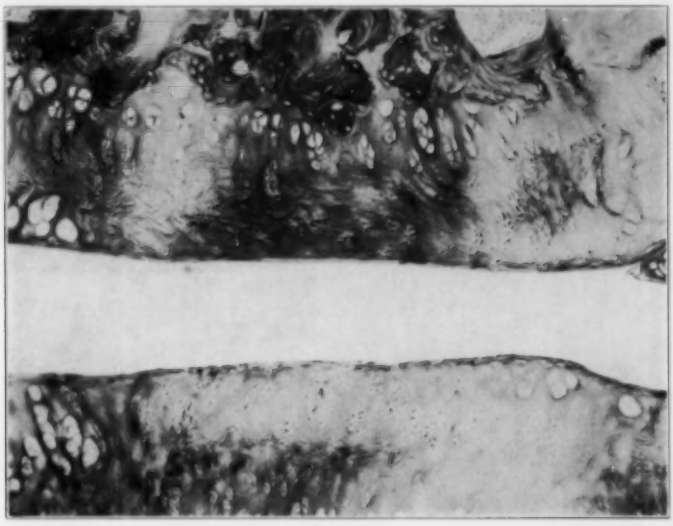

FIG. 5

Immobilization for thirty days. There is a limited area of compression between the medial condyles of the tibia (below) and femur (above). The cartilage cells in this area are small and distorted, and the matrix lacks normal homogeneity. At the periphery of the compression area to the right and left normal cartilage cells are visible (× 120).

In areas where the femoral condyles remained in apposition with the patella, the cartilage retained its normal appearance up to thirty days. After forty-five days of immobilization, in several sections there was some alteration in cell size and staining quality, as well as loss of matrix homogeneity. Tangential fibrillation and fibrillation of the matrix of the articular cartilage could be distinguished in some sections but not in specific or consistent locations.

In one of the knees immobilized for forty-five days and in all the knees immobilized for sixty days, a definite but limited area of the cartilage on the femoral condyle was found to be altered (Fig. 6-A). This area, as determined by examination of serial sections, was rather consistently located on the medial condyle, opposite the distal half of the patella and in a plane parallel to the long axis of the posterior cruciate ligament. The lesions in some instances were true ulcerations in that there was erosion of the superficial layers of cartilage (Fig. 6-B). In other

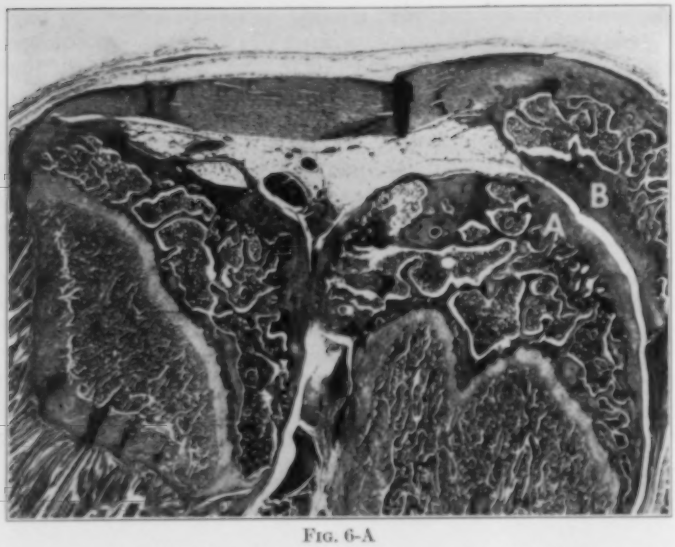

FIG. 6-A

Immobilization for sixty days. Note the area of cartilage erosion (*A*) in the femoral condyle and an apposing area of irregularity in the patellar cartilage (*B*) (× 10).

FIG. 6-B

Immobilization for sixty days. Another section of the lesions shown in Fig. 6-A, with higher magnification. Note the details of the cartilage lesion (*A*) and the nature of the subchondral response (*B*) (× 35).

instances, the lesions seemed to be caused more by compression than by erosion. In some of the more prominent lesions all grades of cartilage alteration were observed. At the periphery there were loss of tangential cells, cell distortion, variation in staining quality, and matrix fibrillation. At the center, the depression or cleft occasionally extended into the radial or calcified stratum. There was no regular gradation of change from the periphery to the center of these lesions, for considerable variation in configuration and severity was found in different animals.

After ninety days of immobilization, the condylar lesions were found to be

of the same nature but more marked in degree. At this time, subjacent to all the cartilage lesions there were changes in the bone of the femoral condyle. These are described in a succeeding paragraph.

In the knees immobilized for sixty and ninety days, the area of the patella immediately apposing the condylar defect showed alterations in the cartilage that were of less extent and severity than those in the condyle.

C. Bone

Alterations in Subchondral Bone

Major alterations in the subchondral bone were limited to the areas underlying the cartilage lesions that have been described. These changes were only observed in knees immobilized for sixty days or more, with the one exception of a knee immobilized for forty-five days. The earliest change was hyperemia: the marrow spaces immediately subjacent to the cartilage lesion were filled with blood or very vascular connective tissue (Fig. 6-B). In the smaller lesions, this vascular

FIG. 8

Immobilization for ninety days. Section taken through the joint surface just outside the central ulcer in the articular cartilage. This subchondral lesion shows a central area of loose avascular connective tissue surrounded by dense vascular connective tissue and confined by remodeled trabeculae. The cartilage overlying this portion of the lesion is intact (× 75).

connective tissue was confined to the spaces between the normal trabeculae and the subchondral plate, but in many sections it appeared to penetrate into the deep strata of the cartilage, destroying the subchondral plate. It also appeared to extend into the subjacent marrow spaces. In the more advanced lesions there was evidence of trabecular resorption, as manifested by active osteoclasis occurring on the surface of trabeculae in contact with the highly vascular fibrous connective tissue (Fig. 7). The size of the subchondral lesions seemed to vary directly with the degree of involvement of the overlying articular cartilage. However, in some instances there was extension of the subchondral lesion beyond the bounds of the cartilage lesion, so that in sections taken at some distance from the center of the lesion the overlying cartilage often appeared undisturbed (Fig. 8). In the larger defects the fibrous tissue retained its high vascularity at the periphery. In some of the more extensive lesions after ninety days of immobilization, there were areas of fibrous tissue that were made up of a loose network of stellate cells. These areas

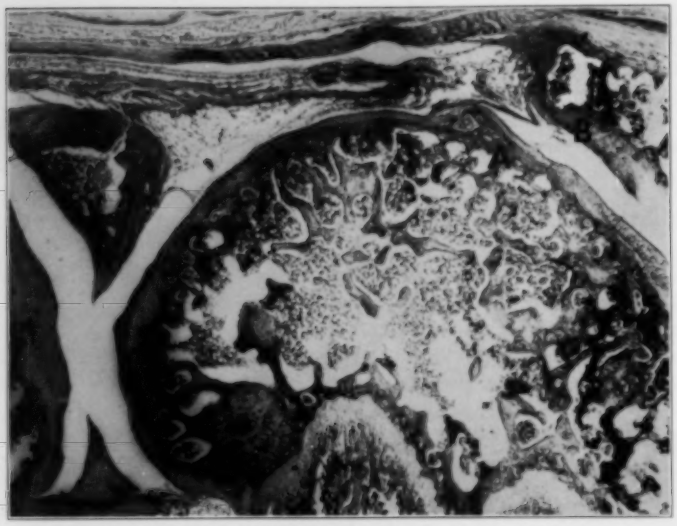

FIG. 9-A

Immobilization for sixty days. An osteophytic cortical excrescence (*A*) is shown in the characteristic location just distal to the lower pole of the patella (*B*) (× 20).

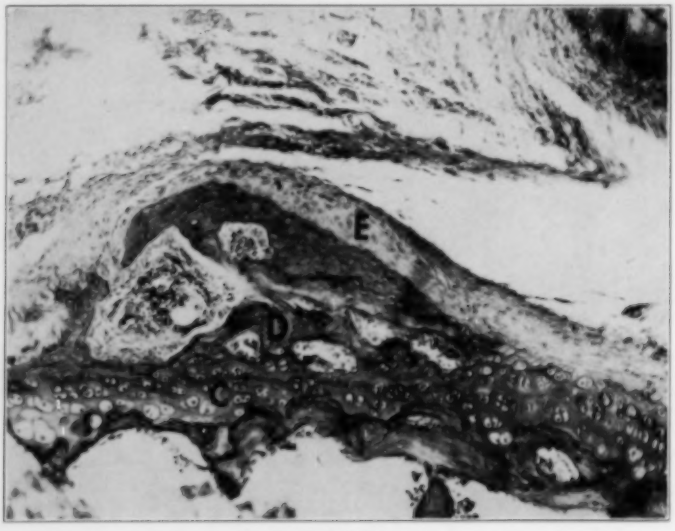

FIG. 9-B

The osteophyte shown in Fig. 9-A. The radial cartilage (*C*), the bone trabeculae (*D*), and the fibrous cap (*E*) are well shown in this high-power view (× 110).

contained no blood vessels but were surrounded by dense vascular fibrous tissue which was in turn delimited by an incomplete osseous capsule. Vacuolation of the loose avascular central fibrous tissue was observed in several sections (Fig. 8). The further development of these subchondral lesions will be considered in the section of this paper on remobilization.

Alterations in Cortical Bone

Cortical atrophy after immobilization could not be satisfactorily demon-

FIG. 10

Immobilization for forty-five days. The animal was sacrificed fifteen minutes after forced remobilization. Note the complete tear (*A*) through the central connective tissue, and the hemorrhage (*B*) in the cleft thus formed (× 25). Compare with Fig. 15.

strated in any of these knees. In the knees immobilized for sixty and ninety days, the slight prominence of the non-articular portion of the medial femoral condyle that overlies the attachment of the posterior cruciate ligament was often expanded, and its cortex was thin. This slight change was inconstant, and we have no explanation for it.

In five knees immobilized for sixty days a transverse cortical excrescence at the level of the lower pole of the patella was observed on the medial femoral condyle (Figs. 9-A and 9-B). This excrescence was hypertrophic, with the histological characteristics of a true osteophyte, and therefore the description of this change might properly be placed in the section on cartilage changes. The new bone in these excrescences lay superficial to the condylar cartilage, and in most sections the calcified and radial layers of the articular cartilage were still visible beneath this new bone. Each osseous excrescence was covered with fibrous tissue and contained only a few trabeculae or marrow spaces. In the knees immobilized for ninety days osteophytes were infrequently observed.

Alterations in Cancellous Bone

Alterations deep to the cortex were limited to moderate trabecular atrophy and resorption and remodeling of the trabeculae associated with the subchondral lesions previously described. There was no alteration of marrow-cell pattern as compared with the control sections.

The epiphyses remained open in all animals, and the pattern of enchondral ossification in control and immobilized extremities was the same. In the extremities of a few older animals, blunting of the epiphyseal plate and apparent progressive closure were observed in both the immobilized and the control extremities. This finding was ascribed to the age of the animals.

OBSERVATIONS AFTER REMOBILIZATION OF PREVIOUSLY IMMOBILIZED JOINTS

Twenty-nine animals from the groups immobilized for forty-five and 110 days were used for the investigation of the effects of remobilization. Immobilization for forty-five days was selected because this was known to produce certain alterations that were present but minimum in nature, whereas 110 days of im-

mobilization was selected arbitrarily as a time when marked alterations were known to be well established. In addition, two animals immobilized for sixty days were used for gross observation of the effects of remobilization. In the group of nineteen animals immobilized for forty-five days, six animals were forcibly remobilized. Of these, one was sacrificed at five minutes, and one at fifteen minutes after remobilization, and four were sacrificed forty-five days after remobilization. Six animals were passively remobilized, and seven animals were actively remobilized for forty-five days each. In the group of ten animals immobilized for 110 days, four were forcibly remobilized, of which two were sacrificed after thirty-five days and two after fifty days; six animals were actively remobilized, of which two were sacrificed after seven days, two after thirty-five days, and two after fifty days. Sections were made of the joints of six other animals that were in effect remobilized because infection at the pin sites caused loosening of the splint. Of these six joints, one was remobilized at thirty days, and the remainder at ninety days. Of the animals that had been immobilized for ninety days, one was sacrificed after thirty days, and the others after 200 days of active remobilization.

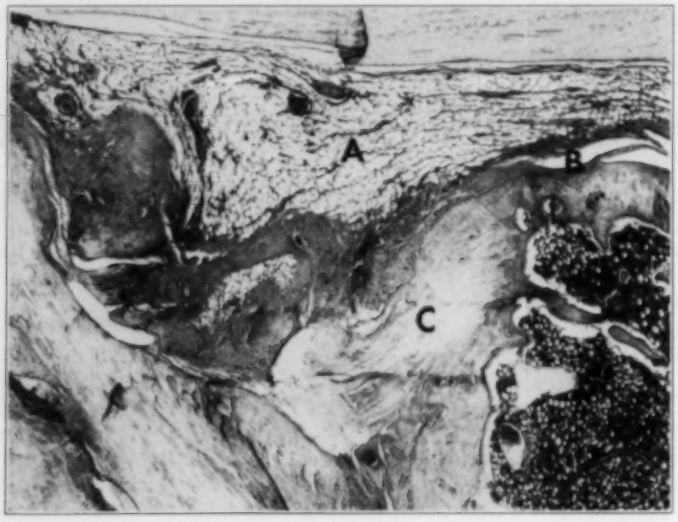

FIG. 11

Immobilization for 110 days; forty-five days after forced remobilization. There is persistence of central connective tissue (*A*), which is rather dense. The joint cleft (*B*) has been re-established to the level of the posterior cruciate ligament (*C*). The bridging strand of connective tissue to the right of *B* is typical of the mobile adhesions seen in remobilized animals (× 25).

Gross Findings

As the previously immobilized joints were forced through a complete range of motion, tearing of soft tissues, which we thought were principally muscles, could be felt. In order to determine in these immobilized extremities how much the motion was limited by capsular contracture and how much by muscle contracture, the muscles were stripped from the immobilized extremities of two freshly sacrificed animals after sixty days of what was considered to be effective immobilization. By this means it was shown that these rats' knees, which were restricted to 30 degrees of extension before excision of the muscles, could be extended freely to 150 or 160 degrees after excision of the muscles. At this point further extension was inhibited by the capsular and pericapsular structures. Müller and Scaglietti and Casuccio recorded similar findings, and there is general agreement among investigators that with limitation of joint motion after immobilization, contracture

of the muscles is a primary alteration that in itself is effective in the restricting of motion of the joint.

After thirty-five or more days of remobilization, there was no well defined difference in the ranges of motion of the joints remobilized by the three methods described. All joints showed a substantial increase in motion. However, the duration of immobilization definitely influenced the final range of motion attained. After forty-five days of immobilization, complete restoration of motion was relatively common, whereas in the animals immobilized for 110 days a complete range of motion was not restored except in those animals observed for 200 days after remobilization. In the knees of these animals, function was restored to almost normal.

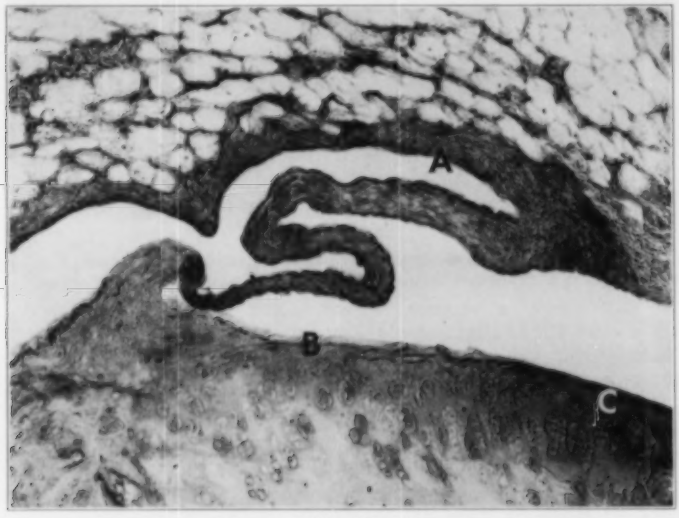

FIG. 12

Immobilization for 110 days; forty-five days after forced remobilization. This elongated adhesion and the adjoining connective tissue show the character of the surface, or lining, cells (*A*) of the newly formed joint cleft. Cartilage adjacent to the adhesion (*B*) shows no tangential layer, whereas that away from the adhesion is intact (*C*) (× 120).

Microscopic Findings

In the two knees that were immobilized for forty-five days and studied five and fifteen minutes after forcible remobilization, the findings were identical. The most striking feature was a tear of the intracapsular connective tissue (Fig. 10) that, as previously noted in the knees immobilized for forty-five days, filled the central region of the joint and formed adhesions to the unapposed joint surfaces. Centrally, the tear was in a different plane than that of the original joint cleft, thus there remained attached to the femoral condyles and to the cruciate ligaments a layer of fatty connective tissue of varying thickness. In other areas the connective tissue was pulled free from the condyles, with only tags of tissue remaining attached to the condyles. The tear was complete, extending from the patella to the condyles of the tibia and peripherally to the menisci. The cleft so formed was filled with blood from torn capillaries. There were no tears of the ligaments or muscle attachments. Hence, it is assumed that any rupture that may have occurred was in the muscle bellies that were not sectioned.

In the 110-day group, the knees of the two animals that were remobilized actively for seven days gained very little motion. One showed no increase in the range of knee motion present after removal of the splint, and microscopic examination of the joint revealed that it resembled the joints immobilized for ninety days.

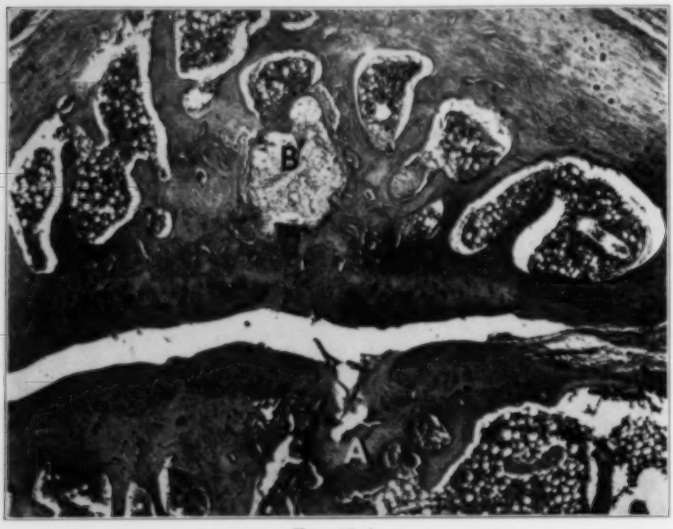

FIG. 13-A

Immobilization for 110 days; seven days after active remobilization started. The lesion of the femoral condyle (*A*) is ulcerative, whereas that of the patella (*B*) is cystic (× 34).

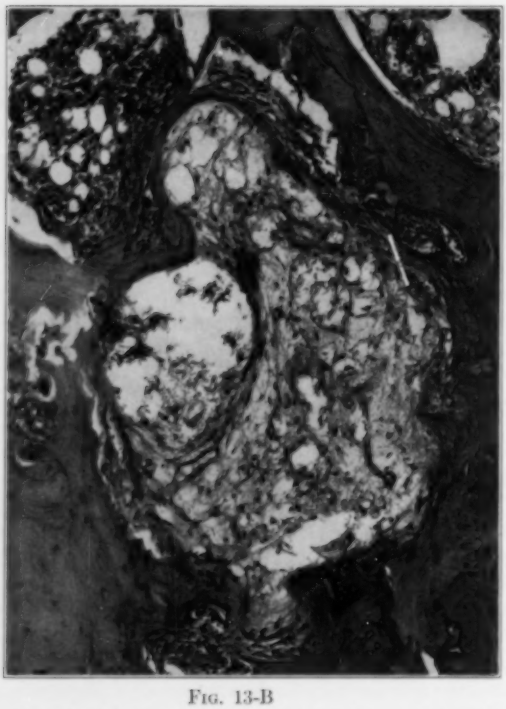

FIG. 13-B

The patellar lesion is filled with loose avascular connective tissue and vacuoles containing cellular debris. There is little or no vascular connective tissue at the periphery (× 120).

FIG. 13-C

In the region of the central opening (*C*) the patellar lesion (*B*) is almost empty. The femoral lesion (*A*) is limited to the subchondral region in this section (× 25).

However, there were prominent lesions on the condyles and the patella, which will be described later. The other animal had four to five millimeters of knee motion when the splint was removed and at the time of sacrifice was using the knee freely. On microscopic examination this knee showed only slight tearing of the connective tissue distal to the patella.

After thirty-five or more days of remobilization, the findings in the knees of the three groups of animals were very similar, regardless of the duration of immobilization. In all, there was limited restoration of the joint cavity. The central area remained filled with connective tissue, but the re-established joint cleft extended to or slightly beyond the femoral attachment of the posterior cruciate ligament (Fig. 11). In many sections the central connective tissue appeared to be more dense than that seen in the immobilization groups. On all surfaces of the cleft, the connective-tissue cells had become closely aligned and had the appearance of synovial-lining cells (Fig. 12). Often, the femoral condyles had become free of adhesions except for some areas where a layer of connective tissue remained. The more mobile adhesions persisted as strands that assumed various forms (Figs. 11 and 12). The cartilage underlying the persisting adhesions and connective tissue in these remobilized knees appeared to be slightly thinner than that in comparable areas in knees immobilized for sixty and ninety days. Those limited areas of cartilage that had been freed of connective-tissue attachment were probably those where the adhesions were not firmly established during immobilization, and the underlying cartilage thus remained intact (Fig. 12).

If it is assumed that in all the forcibly remobilized joints a complete tear was created similar to that found in the animals sacrificed immediately after this maneuver, it is apparent that this cleft was not maintained in the central area by the subsequent activity of the animal because the remaining clefts in these forcibly mobilized knees were of the same extent as those in the actively and passively remobilized joints.

Although complete serial sections of the knees remobilized actively for 200 days were not available, it could be ascertained that the encroaching connective tissue and adhesions had persisted even after this long period of restored joint function.

In the knees immobilized for 110 days, all the cartilaginous and subchondral alterations persisted, and the lesions were larger than those observed in the knees immobilized for ninety days. Two morphological configurations were predominant: a cartilaginous defect that was a broad and deep ulcer or cleft with extension of the subchondral fibrous tissue well down into the cancellous bone of the condyle (Fig. 13-A); or a relatively small or shallow surface defect associated with a subchondral defect that was distinctly cystic (Fig. 14). The fibrous tissue underlying the ulceration of the cartilage was always dense and showed moderate vascularity, but small areas of hypervascular connective tissue could be seen at the periphery of the fibrous lesions. These lesions were very similar to those seen in the knees immobilized for sixty and ninety days. The cystic-appearing lesions consisted of loose stellate and often vacuolated avascular fibrous tissue surrounded by dense vascular fibrous tissue and an incomplete osseous capsule. These lesions duplicated on a larger scale the more discrete areas of loose connective tissue described in the section on immobilization. In every instance these lesions communicated with the joint cavity, but the opening was often partially filled with fibrous tissue (Fig. 14). The vacuoles sometimes contained what appeared to be cellular debris. In one of the joints remobilized for seven days, there was an ulcerative lesion of the femoral condyle and a cystic lesion of the patella (Figs. 13-A and 13-C). The patellar lesion showed large vacuoles that contained dead cells. The remaining connective tissue in the lesion was totally avascular and necrotic, and there was no hypervascular tissue at the periphery (Fig. 13-B). In the area of the central opening, the cyst was almost devoid of contents (Fig. 13-C). Patellar lesions in these remobilized knees were often more pronounced than those in the knees that had been immobilized for ninety days.

Small intracondylar cysts were occasionally observed in both the control and the immobilized joints of the 110-day group. These are described in the succeeding paragraph.

CONTROL JOINTS

In the control joints the joint space in all groups was free, and there was no evidence of adhesion in any area (Fig. 15). No alteration in the cartilage was found except in the control knees of the animals in the 110-day immobilization group, where small cysts were observed in the intermediate strata of the condylar cartilage. These cysts were partially or completely filled with amorphous material that was usually disposed transversely in a fibrillar manner (Fig. 16). The cartilage cells to either side of the cysts were oriented according to the shape of the cysts, whereas those superficial to the lesions appeared to be compressed. Similar cysts were observed in the immobilized joints of the same animals. Sokoloff and Jay described these intracartilaginous cysts as the only consistent manifestation of degenerative joint disease in the rat. Their study of 157 rats indicated that the rat was resistant to spontaneous development of osteo-arthritis.

The knee joints of those animals in which only pins were applied showed no abnormality.

ANALYSIS OF FINDINGS

Immobilization Experiments

Our method of fixation of the joint permitted weight-bearing and allowed a small arc of motion that varied slightly among the animals. Alterations consequent to this type of restriction of motion involved all the major intra-articular elements. It is likely that the degree and even the character of these changes would be modified appreciably by a different means of fixation.

We are of the opinion that in any type of experimental immobilization of a joint, three factors determine the quality and extent of alterations that occur: (1) the degree of restriction of motion; (2) the amount of friction between the joint surfaces that are in contact; and (3) the amount of pressure on these contact

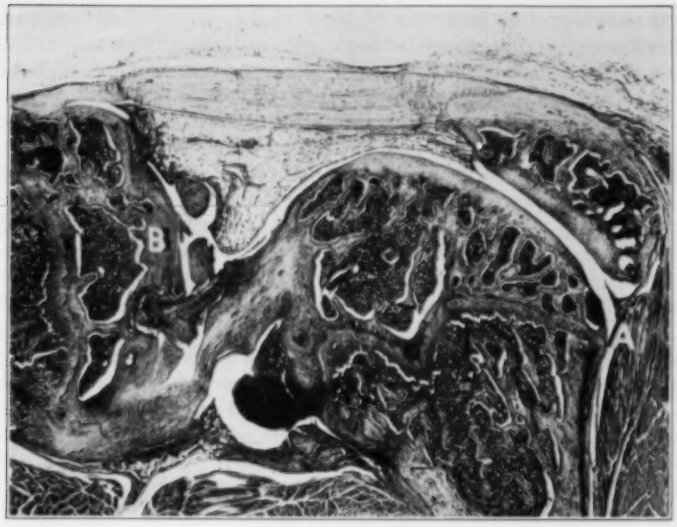

FIG. 15

Control joint; section through the center of the joint. The joint cavity is free, the cleft extending from the suprapatellar pouch (*A*) to the condyle of the tibia (*B*). There are no adhesions and no cartilage irregularities (× 10). Compare with sections of immobilized joints.

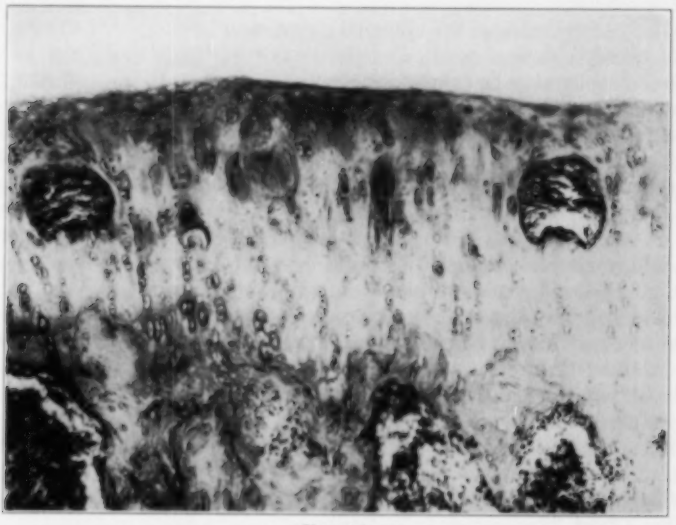

FIG. 16

Control joint. These small intracartilaginous cysts were observed in both control and immobilized joints. Their characteristic configuration and amorphous content are shown (× 120).

surfaces. Ekholm and Norbäck showed experimentally that physiological exercise of a joint increases the volume of synovial fluid in the exercised joint, as compared with that in the opposite, unexercised joint. If we assume that the converse is true, then there is a decrease in the volume of synovial fluid in an immobilized joint. Furthermore, encroachment of connective tissue on the articular surface and adhesions further diminish the amount of synovial fluid. Under these circumstances, the remaining articular cartilage should be more vulnerable to injury by friction and pressure.

If we consider the total sequence of changes—including proliferation of connective tissue, formation of adhesions, and cartilage alteration—as they relate to limitation of motion, we may devise a reasonable concept of the pathogenesis of these changes that has no claim to originality. In the normal joint, intracapsular connective tissue remains mobile, and the synovial cleft is retained as long as there is a normal arc of motion. With prolonged limitation of motion, as was the case in these joints, the connective tissue proliferated and filled the regions that were no longer functioning parts of the joint. Articular surfaces that remained consistently unapposed by other cartilage were covered by proliferating connective tissue. At these points of contact between the connective tissue and the cartilage, adhesions formed that at first were loose in nature but subsequently became more and more permanent as the underlying cartilage cells changed in form. This apparent transformation of cartilage cells into connective-tissue cells and the consequent thinning of the cartilage may have been caused by loss of adequate surface nutrition and the relative hyperemia of the overlying connective tissue. It is possible that once the cartilage and connective tissue became confluent there was established a nutritional equilibrium that permitted the cells of the deeper strata to remain viable and unaltered.

So-called fibrous degeneration of cartilage has long been recognized clinically, and the sequence of changes has been recorded by other investigators. Perhaps the earliest description of this phenomenon as observed experimentally is that of Carl Reyher, who in 1874 related in detail the process of cellular alteration. He stated: ". . . beyond those parts of the articular surfaces which are habitually in contact, the large, flattened, round cartilage-cells pass, by the gradual acquisition of cell-processes, into the spindle-shaped or stellate connective tissue corpuscles of the synovial membrane" [17].

The changes in the connective tissue and cartilage described in the preceding paragraphs may be ascribed logically to the limitation of motion. Limitation of motion alone, however, cannot account for the lesions of the femoral condyles and patella, which were the most striking of our findings. These lesions varied from slight compression to gross erosion of the cartilage, with, in every instance, an adjacent subchondral lesion. The relatively consistent location of the lesions among these animals suggested that the mechanism of production was related to the method of fixation, which created a discrete area of patellocondylar friction and pressure. The location of this area did not vary appreciably in either the medial or lateral direction, but it did vary slightly with reference to the long axis of the patella. These slight differences in location were probably due to different levels of fixation of the splints to the tibiae and femora. Thus, as the animals walked, limited excursion of the patella occurred, and, at maximum possible flexion, abnormal pressure was developed between the patella and medial femoral condyle at a consistent point. The location of this point varied according to the level at which the splint was attached. Because of the limitation of joint motion and the encroachment of connective tissue, the condylar and patellar cartilages were deprived of their normal lubrication and nutrition from the synovial fluid. Thus compromised, they were more liable to damage by friction and pressure, and tangential and matrix fibrillation and cleft formation occurred in the hyaline cartilage. In this manner we explain the surface or cartilage lesions.

It is not so simple to explain the subchondral defects. In our opinion the appearance of the very vascular connective tissue or granulation tissue in the subchondral marrow spaces could be explained in two ways: (1) as a healing reaction in response to damage limited to the cartilage—an effort of the marrow vessels to supply elements of nutrition and repair—or (2) as a healing reaction to injury to the subchondral bone caused by forces transmitted through the cartilage, presumably fatigue and fracture of the subchondral plate. Once erosion of the cartilage had occurred down to or through the subchondral plate, or once there was a connecting cleft between the subchondral bone and the joint, the

development of a subchondral lesion could be expected. It is probable that connecting clefts between the subchondral bone and the marrow may be established without fracture because in the subchondral plates of normal animals there are many openings [2,5,6,7,8] through which small vessels pass to form vascular buds in the deeper layers of the cartilage. A cartilage ulcer or matrix cleft might easily communicate with one of these openings (Fig. 17). We have noted previously that in many instances the initial vascular response appeared to be located in one of these vascular buds. Probably, it is a combination of factors that accounts for the subchondral response, but somehow it seems less important to establish the exact mechanism than to recognize that these lesions would not have existed were it not for the surface stimulus.

Once the subchondral lesion was established, the developmental sequence was not difficult to follow. As the hypervascular granulation tissue eroded the adjacent trabeculae, the lesion continued to enlarge. This process persisted as long as the tissue retained its blood supply. With expansion of the lesion, however, the central area became less and less vascular, and, eventually, contained loose fibrous connective tissue in which there were no capillaries. Peripherally, the vascular connective tissue persisted, and an osseous capsule composed of remodeled trabeculae developed. The thickness of these trabeculae suggested that there had been reactive new-bone formation. Once the lesion had attained this configuration it could be described as cystic in appearance. As the vascular fibrous tissue receded to the periphery, the central area began to show vacuolation. With still further peripheral recession of the vascular granulation tissue, the fibrous tissue in the center became necrotic and was resorbed. The osseous lesion thus gradually became truly cystic without cellular contents.

If we accept this concept of the pathogenesis we may state that as long as there is adequate blood supply for the fibrous tissue within a cystic bone lesion the lesion will remain filled with dense fibrous tissue. However, if this fibrous tissue is gradually deprived of its blood supply, this tissue first will become a loose mesh of stellate cells and then in time will die when its blood supply becomes inadequate. Thus, on microscopic section, a subchondral cyst may appear filled with fibrous tissue or may be almost empty, depending on the blood supply. These two possibilities were well shown in our animals.

One additional alteration observed in these experiments, the condylar osteophyte, was probably produced by the altered joint mechanics rather than by the joint immobility *per se*. The consistent proximity of the osteophytes to the distal pole of the patella suggests that this area on the condyle was subjected to friction and pressure from the patella sufficient in some of the animals to initiate enchondral ossification.

Although other writers [4,13,16,19] have recognized the importance of friction or pressure, or both, in the creation of cartilage defects, they have not clarified the relationship between these forces and the limitation of motion. We have attempted to point out that limitation of motion *per se* will cause certain alterations, such as: proliferation of the connective tissue; formation of the adhesions; and the thinning of the cartilage underlying the adhesions. Limitation of motion will also so compromise the nutrition of the articular cartilage that the cartilage is more liable to injury by forces of friction and pressure that, under the conditions of immobilization, are applied in a restricted area rather than being normally distributed. Reyher used immobilization in plaster casts on dogs, with extension of the plaster cast onto the trunk. He described only connective-tissue proliferation with adhesions to and thinning of the unapposed hyaline cartilage, although he alluded to slight decubitus of the articular cartilage. Müller immobilized the extremities of some of his animals in subcutaneous thoracic pouches; in others he restricted motion by wiring of the calcaneus to the tibia, but permitted weight-bearing. For the pouch-restricted joints he reported no significant alterations aside from atrophy of the bones; for the joints that were wired, he described

involvement of all joint elements, including erosion of the cartilage in pressure areas. Whereas Reyher insisted that the minimum change in his animals could be ascribed to the efficient immobilization, Müller was of the opinion that the more efficient the fixation, the greater the amount of change. In his opinion the preservation of the joint surfaces in Reyher's animals was the result of some degree of motion that must have been present in the casts. Scaglietti and Casuccio immobilized the knee joints of dogs in plaster casts in semiflexion and in full flexion. The animals with their knees in semiflexion could bear weight, whereas those with full flexion could not. Only the joints of the semiflexion group showed cartilage ulceration in addition to other findings of less magnitude.

In Müller's first group of animals, the joints of the extremities enclosed in subcutaneous pouches remained largely intact not merely because there was motion but because of the relatively friction-free arc of motion; whereas in the ankles fixed with wires there was ulceration of the cartilage because of repeated weight-bearing pressure in one area in a joint compromised by restriction of motion. Scaglietti and Casuccio, as noted, found cartilage ulceration only in those joints subjected to weight-bearing pressure. Thus, it seems apparent in these two instances that it was the pressure that determined the degree of change and not the security of the immobilization alone. Ely and Mensor, basing their observations on four dogs immobilized in plaster casts, concluded that joint changes, including erosion of the cartilage, may occur without complete immobilization. Their animals were weight-bearing and had limited motion only. Again, it appeared to be the friction and pressure superimposed on restricted joint motion and not the degree of limitation of motion that accounted for the cartilage lesion.

Trias demonstrated cartilage ulceration and subchondral cyst formation in rabbit knees subjected to compression forces only. Salter demonstrated similar destructive changes in rabbit knees with the application of compressive forces of considerable magnitude.

Viewing all the changes resulting from limitation of motion of the rat knee, it occurred to us that these alterations, including cartilage erosion, subchondral cysts, and osteophytes, are similar to the changes observed clinically in aging joints and in joints with osteo-arthritis. It seems possible that with limitation of motion of the rat knee, the aging process is accelerated by the encroachment of the connective tissue on the joint space and the consequent deficient nutrition of the articular cartilage. In any event, the sequence of changes in the immobilized rat knee, although artificially induced, is much the same as that observed during normal aging.

Remobilization Experiment

In the experiments with remobilization of previously immobilized rat knee joints the techniques for mobilization were similar to those used clinically: forced remobilization followed by active motion; daily passive motion; and active motion only. In general it may be stated that there were no important differences in the findings among the three groups.

Gross examination revealed that it is the muscular rather than the capsular structures that account for most of the restriction of motion after immobilization. The longer a joint is immobilized, the more time is required to remobilize it, whatever means are employed; these are established clinical observations.

Forced remobilization caused a complete tear of the connective tissue within the joints, forming a central joint cleft at a plane different from that in the joint originally. This cleft was not maintained by the subsequent activity of the animal, so that after thirty-five days of remobilization there was no difference in the extent of the joint clefts in the three groups of animals. If the joints of the forced group had been taken through a complete range of motion daily, it is possible that the cleft established with the first manipulation could have been maintained. The limited restoration of the joint space in all three groups may be ascribed to the

fact that the rat rarely extends the knee completely under normal circumstances. Hence, the joint spaces in these knees were restored just to the extent required for the activity of these animals.

The separation and elongation of the intra-articular adhesions suggest that these adhesions gradually become adapted to the increasing range of joint motion in these rats' knees. Since the central connective tissue and adhesions persisted even after 200 days of active remobilization, this adaptation was apparently sufficient to allow adequate motion, and complete freeing of the joint surfaces was not necessary to restore a functional or even a normal range of motion. Thus, proliferated connective tissue and adhesions appeared to be more or less permanent changes.

As was anticipated, the synovial membrane was re-established in the newly formed joint spaces through modification of surface connective-tissue cells in all the animals. The classic work of Key is well known, but in the literature we have not found any reference describing the demonstration of the recognized capacity of connective-tissue cells to differentiate into synovial cells by the means here employed.

In these experiments, only small areas of articular cartilage were free of adhesions after remobilization, and in these the superficial layers of cartilage were intact. On most of the condylar surfaces there remained a thin layer of connective-tissue cells. The cartilage underlying this layer showed no difference in structure or viability from that in the immobilized joints, even after 200 days of remobilization. It seems probable, under these conditions, that the cartilage cells underlying adhesions may remain identifiable and viable for an indefinite period.

In the considering of the persistence of the major cartilage and subchondral lesions in these joints, it was impossible to determine to what degree and in what manner these lesions were affected by restoration of joint motion. Certainly, there was no evidence after thirty-five days of remobilization that healing of the lesions was taking place.

SUMMARY AND CONCLUSIONS

This is a histological study of rat knee joints that were subjected to limitation of motion alone or were remobilized after varying periods of restricted movement. A progression of morphological changes consequent to restriction of motion was found, and it was possible to gain some indication of the degree of reversibility of these changes after varying periods of immobilization and remobilization either by a single forced manipulation, or by active movement alone, or by repeated gentle passive movement. On the basis of this study, we have arrived at the following conclusions in regard to experimental joint immobilization and remobilization in the rat:

1. Rigid immobilization is not essential to produce structural change, and the maintenance of a slight range of motion will not prevent structural changes;

2. After prolonged immobilization, contracture of both the muscles and the capsule is responsible for restriction of motion, with shortening of the muscles being primarily at fault;

3. Proliferation of intracapsular connective tissue and the formation of adhesions are primary responses to limitation of motion—to a limited degree these changes are reversible;

4. Major cartilage alterations, such as matrix fibrillation, cleft formation and ulceration, as well as their adjacent subchondral lesions, result from abnormal friction and pressure in a joint compromised by limitation of motion—these changes are not reversible;

5. In the rat, the joint changes that are caused by restriction of motion appear to be reversible if the period of immobilization does not exceed thirty days—after sixty days of immobilization all major joint alterations consequent to the restriction of motion have appeared, and further immobilization after this time only causes changes in the degree of these alterations;

6. With forced remobilization there is tearing of the connective tissue that has proliferated within the joint, often in a plane different from that of the original joint cleft; subsequently, associated with continued motion of the joint, a cellular layer with the characteristics of synovial membrane forms about the surfaces of the new cleft;

7. Three methods of remobilization—forced, active, and passive—were used in these experiments, which were equally effective in restoring of the range of motion; after thirty-five days of remobilization by any means the joints were histologically indistinguishable.

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Fracture of the Carpal Navicular

Diagnosis, Non-operative Treatment, and Operative Treatment *

BY DR. OTTO RUSSE, VIENNA, AUSTRIA

Fracture of the carpal navicular is an important injury in accident surgery. Poor treatment or no treatment leads to non-union and may cause a painful and severely disabled wrist. In time, severe arthrotic and degenerative changes develop that rule out the possibility of bone-grafting and may necessitate such a drastic measure as arthrodesis. Early diagnosis and adequate treatment of this injury, however, yield full recovery in almost 100 per cent of the patients. Operative treatment of non-union has led to bone union in 80 to 90 per cent of the patients seen by me.

Fig. 1-A

Fig. 1-B

Skeleton of the right wrist seen from the volar (Fig. 1-A) and dorsal (Fig. 1-B) aspects. The entrance of the vessels from the dorsal side is clearly shown, indicating the advantage of the volar approach.

DIAGNOSIS

Roentgenographic Technique

If there is tenderness in the region of the navicular, a fracture of this bone should be suspected, especially if this sign develops after a fall on the dorsiflexed hand or a blow on the palm with the wrist in dorsiflexion. In such cases it is considered preferable routinely to make the following roentgenograms (Fig. 2): (1) a dorsovolar view, with the forearm in neutral position mid-way between pronation and supination and the wrist in slight dorsiflexion with the fingers closed into a fist; (2) a similar view, with the forearm in 15 to 20 degrees of supination; (3) a true lateral view with the forearm in 90 degrees of supination; (4) a dorsovolar view, with the forearm in 15 to 20 degrees of pronation. Ulnar deviation of the wrist while these roentgenograms are made should not exceed 10 degrees with fresh fractures to avoid distraction of the fragments. These four roentgenograms are made on one film, eighteen by twenty-four centimeters (with the use of a lead shield). Only in exceptional cases is it necessary to have further oblique views in 80, 70, 60, and 50 degrees of supination or in 40 degrees of pronation.

In the presence of pain without definite roentgenographic findings, even when the film is studied with a magnifying glass, the recommended procedure is to apply a cast for two weeks and then repeat the roentgenograms. Should tenderness on

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1960.

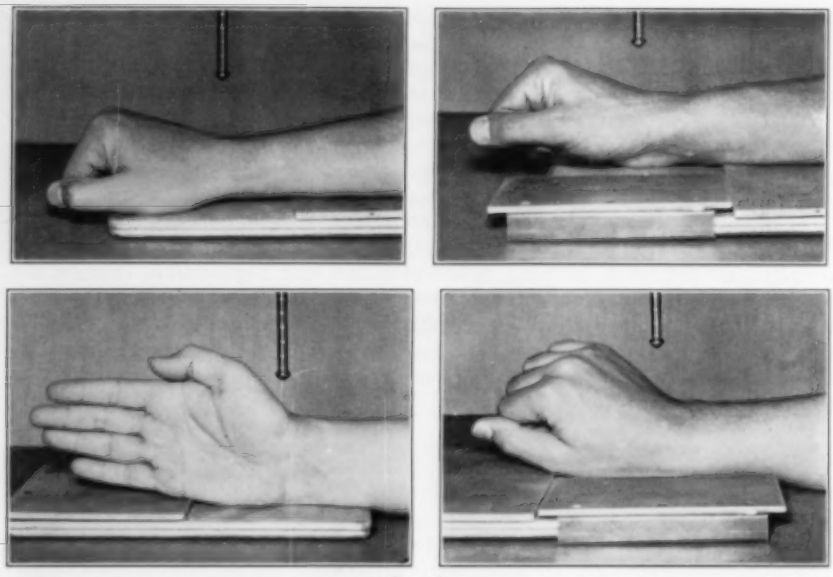
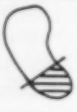


FIG. 2

Photographs indicating positioning for roentgenograms (routine navicular series); four views are made on one film, eighteen by twenty-four centimeters.

TABLE I

LOCATION OF FRACTURE AND APPROXIMATE TIME FOR UNION		
	LOCATION	UNION
	DISTAL THIRD 10 %	6 - 8 WEEKS
	MIDDLE THIRD 70 %	6 - 8 WEEKS
	PROXIMAL THIRD 20 %	10 - 12 WEEKS

pressure or pain on wrist movement persist at this time, even to a slight degree, the wrist should again be immobilized, and the roentgenograms repeated after another two weeks (that is, four weeks after injury). Fissured fractures of the navicular occur that can be demonstrated only after three to four weeks, when absorption has widened the fracture cleft.

Location of Fractures (*Table I*)

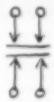
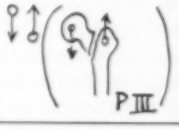
In round figures, 70 per cent of navicular fractures are located in the middle third, 20 per cent in the proximal third, and 10 per cent in the distal third of the

bone. Since most of the blood vessels enter the navicular in the distal part (the tuberosity) and on the dorsal aspect of the middle part (the waist) of the bone, the conditions for healing are better with fractures in the distal and middle thirds. Therefore, the average time necessary for bone union to occur is longer for fractures in the proximal third, in which the time amounts to ten to twelve weeks, than for most fractures in the distal and middle thirds for which six to eight weeks of immobilization is necessary.

TABLE II

TYPES OF FRACTURE AND RECOMMENDED TIME OF IMMOBILIZATION		
TYPE IN RELATION TO LONG AXIS OF NAVICULAR		IMMOBILIZATION
	HORIZONTAL OBLIQUE 35 %	DISTAL THIRD 6 WEEKS MIDDLE THIRD 6 WEEKS PROXIMAL THIRD 10-12 WEEKS
	TRANSVERSE 60 %	6 WEEKS (+ 4 TO 6 WEEKS)
	VERTICAL OBLIQUE 5 %	10 - 12 WEEKS

TABLE III

CAUSE OF FRACTURE AND FORCES ACTING ON THE NAVICULAR			
CAUSE OF FRACTURE	TYPE OF FRACTURE	IF HAND AND FINGER MUSCLES CONTRACT	
FLEXION OR RUPTURE FORCE SUCH AS A FALL ON OR A BLOW TO DORSIFLEXED WRIST	HORIZONTAL OBLIQUE		COMPRESSION FORCES
	TRANSVERSE		
SHEARING FORCE ACTING IN THE LONG AXIS OF FIRST AND SECOND METACARPAL	VERTICAL OBLIQUE		SHEARING FORCES

TYPES OF FRACTURES

The duration of immobilization necessary, as well as the possibility of bone union, depends not only on the blood supply but also on the type of fracture and on the forces acting on the fracture surfaces (Table II). Trojan and Jahna, who studied the data on 500 fractures of the navicular collected by Böhler in the period

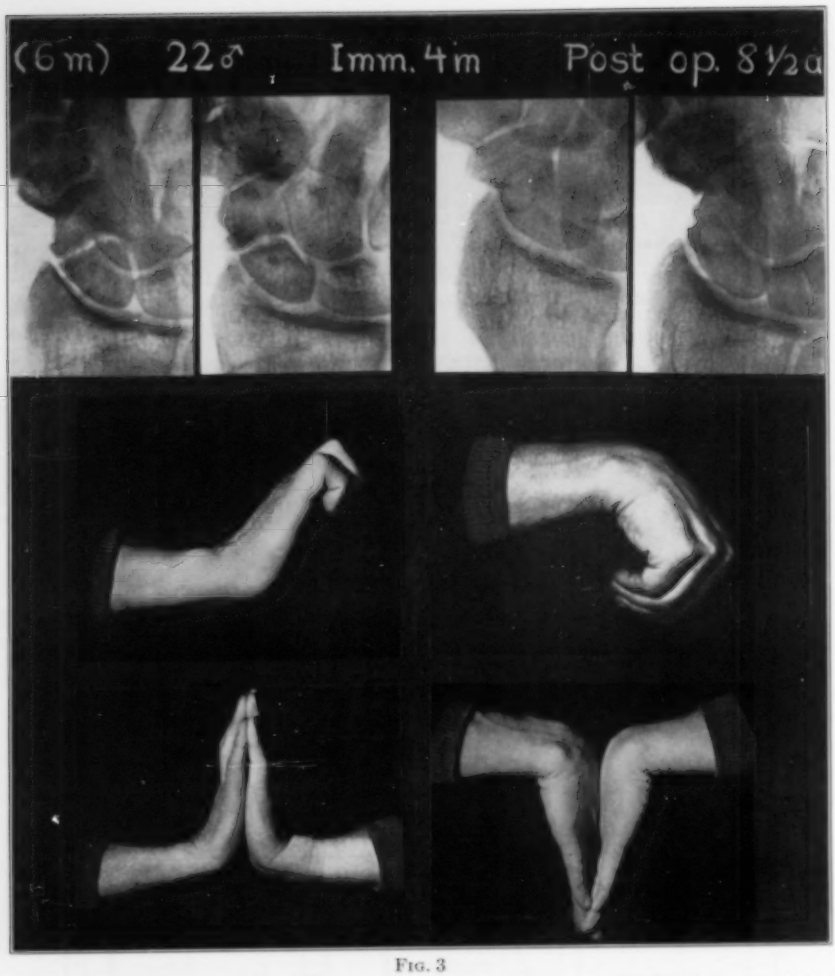


FIG. 3

The patient was a mechanic, twenty-two years old at the time of operation. The two oblique roentgenograms at the upper left show pseudarthrosis of the navicular six months after injury. There was immobilization in plaster for four months after operation. The two oblique roentgenograms at the upper right were made eight and a half years after operation. Active and passive movements eight and a half years after operation are seen in the four photographs.

from 1925 to 1952, distinguished between transverse and oblique fractures according to the relationship between the long axis of the navicular and the fracture line as seen in the dorsovolar view. Follow-up studies of 220 fresh fractures (1956 to 1958) treated by my group have confirmed that the prognosis is best in the horizontal oblique type of fracture (Table III). Most of these fractures healed within six weeks because the forces exerted by the wrist and finger muscles tend to compress the fracture surfaces. In the transverse type of fracture the plane of the fracture cleft is not exactly vertical to the long axis of the forearm. Because of this oblique relationship, both compression and slight shearing forces act on the fracture surfaces, and some of these fractures do not unite in six weeks and need further immobilization for four to six weeks more. In the rare vertical oblique type of fracture the fracture cleft lies in the long axis of the forearm. This type is sometimes difficult to visualize in the routine roentgenograms, and the previously mentioned special supination views should be made. The fracture is sometimes

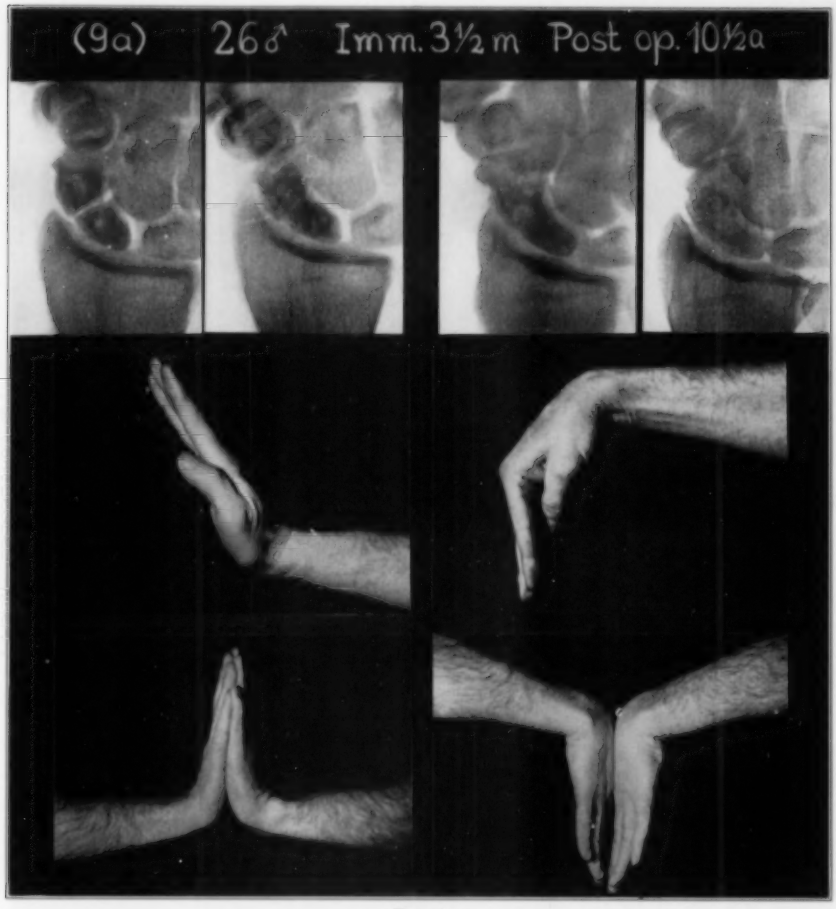


FIG. 4

The patient was an electrician, twenty-six years old. The roentgenogram at the upper left shows pseudarthrosis of the navicular nine years after injury. The second roentgenogram was made after removal of the cast at three and a half months after operation. The two roentgenograms at the upper right show the result at ten and a half years after operation. Photographs show active and passive movements ten and a half years after operation.

clearly seen as an almost longitudinal line that is visible only in these supination views or in the lateral view. This vertical oblique type of fracture may result from a force that strikes the thenar region and is transmitted along the long axis of the first two metacarpals to exert a shearing force on the navicular. The prospect for bone union is not so good in this as in the other types of fractures because the wrist and finger muscles exert an almost pure shearing force on the surfaces of the fracture. This type of fracture may very well be compared with Pauwels's Type III fracture of the femoral neck, whereas the horizontal oblique and the transverse types resemble Pauwels's Types I and II fractures. Immobilization in the vertical oblique type should be continued for at least ten to twelve weeks.

SIGNS OF UNION

We all know that immobilization in fractures of the navicular should be continued until the roentgenograms show definite signs of bone union. It is important to recognize these signs in order to avoid unduly prolonged immobilization. In the absence of clearly visible osseous trabeculations bridging the former

FIG. 5

The patient was a man twenty-three years old. The two oblique roentgenograms at the upper left show pseudarthrosis of the navicular ten months after injury. The two oblique roentgenograms at the upper right were made nine years after operation; there was immobilization in a plaster cast for four months after operation. The four photographs at the bottom show active and passive movements nine years after operation.

defect, one should look for increased density of the bone at the site of the former fracture cleft or on each side of the cleft. It is not generally known that these calcified bands in the fracture site or on both sides of the fracture site are signs of bone union in fresh fractures of the navicular[2,7]. Such calcifications occur in about 40 per cent of fresh fractures. In old fractures, of course, these bands cannot be considered as signs of bone union.

IMMOBILIZATION

Plaster Cast

A fresh fracture should be immobilized in an unpadded plaster cast that extends from the elbow to the metacarpophalangeal joints. The wrist is immobi-

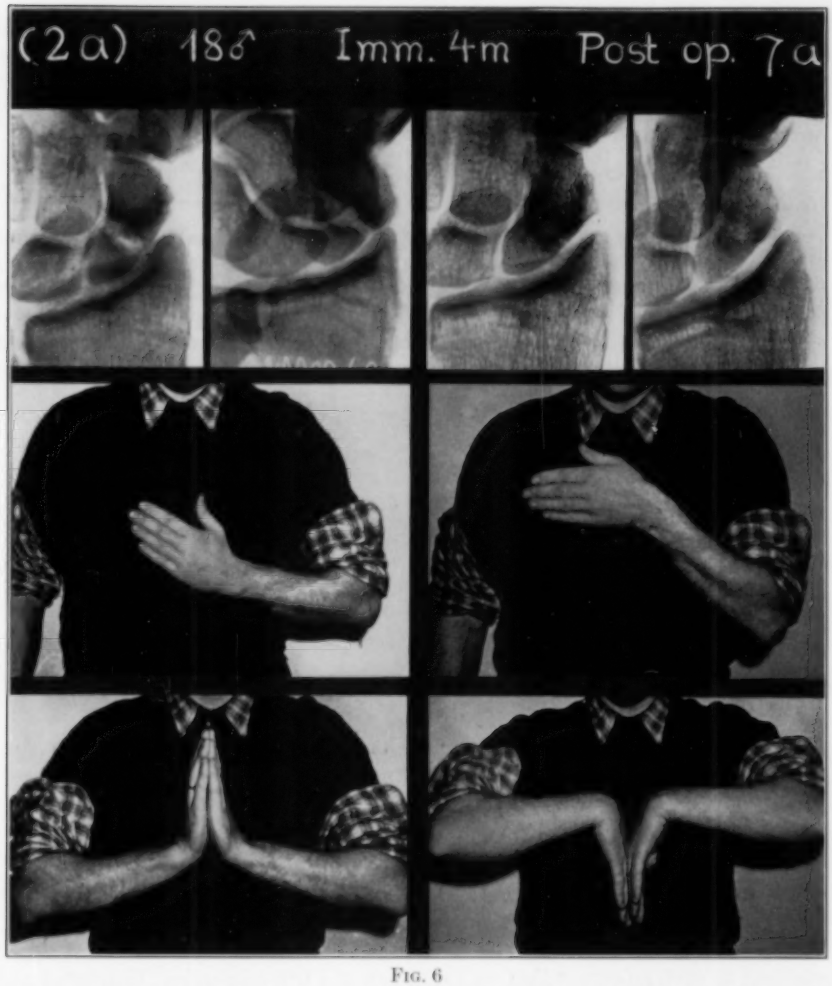


FIG. 6

The patient was a baker, eighteen years old, with pseudarthrosis of the navicular two years after injury (the two oblique views at the upper left). The two oblique views at the upper right were made seven years after operation; there was immobilization in a plaster cast for four months after operation. Active and passive movements are shown in the four photographs below seven years after operation.

lized so that the third metacarpal is in line with the long axis of the forearm with no dorsal or volar flexion and no radial or ulnar deviation. On the day of the injury a dorsal plaster splint is applied, and on the following day the cast is completed by the addition of a volar plaster splint and a circular plaster bandage. The first metacarpal is included in the cast but not the thumb. Movements of the thumb and of the other fingers exert useful compression of the fragments. Mobility of all finger joints is kept completely free. For fractures of the vertical oblique type the fist cast[3], which extends to the finger tips and prevents all finger or wrist motion, is sometimes used. All casts must be carefully checked at least once a week. A defective or loose cast must be replaced immediately.

Duration of Immobilization

Fractures of the middle or distal thirds should be immobilized in an unpadded

plaster cast for six weeks, and fractures of the proximal third and all vertical oblique fractures should be immobilized for ten to twelve weeks. Some of the transverse fractures do not heal in six weeks and need additional immobilization for four to six weeks. After removal of the cast the routine roentgenograms must be made and studied carefully for evidence of bone union.

CONSERVATIVE TREATMENT OF FRESH AND OLD FRACTURES

Healing Process

Fractures of the navicular immobilized in a cast either heal by visible osseous union or show the previously mentioned signs of consolidation in the form of one or two dense bands. In the absence of immobilization, the fracture cleft widens within a few weeks because of absorption of the fracture ends, and two or three months after the accident further absorption leads to the so-called traumatic cavity. Only after several months or years do the fracture ends become

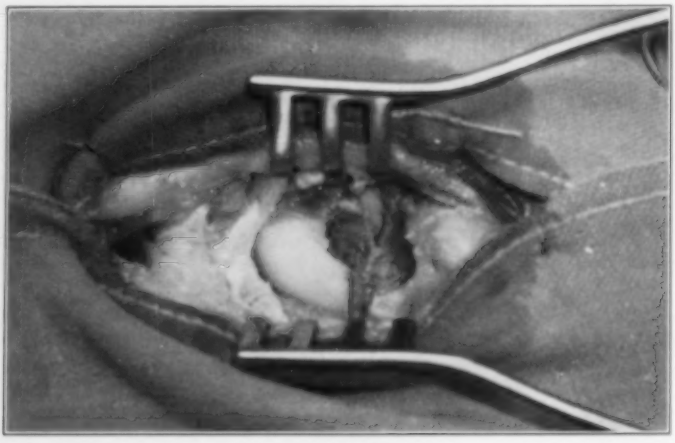


FIG. 7

Photograph made at operation, showing the right carpal navicular exposed by the volar approach. The tendon of the flexor carpi radialis is retracted ulnarward. Both fragments are excavated and ready for insertion of the chips of cancellous bone.

sclerosed to such an extent that we can speak of a true non-union. Untreated and ununited fractures of the navicular may lead to the development of cysts in the navicular and in the neighboring bones. Aseptic necrosis of the navicular may ensue, as well as such severe changes as bone deformity and severe arthrosis of the navicular, the radial styloid, or all the bones of the wrist joint. Established non-union should be treated by bone-grafting, provided severe arthrotic changes have not yet developed. Earlier stages, including delayed union and traumatic cavities, respond well to plaster-cast immobilization of sufficient duration. But since the period of immobilization may in some cases require many months, operative treatment by an experienced surgeon may be considered preferable. Increased density of the proximal fragment as a result of severance of the nutrient blood vessels develops in about 30 per cent of fresh fractures. This is a reversible change and not an absolute indication for operative intervention. As soon as circulation improves by the ingrowth of new vessels from the fracture site, the area of density recedes from the fracture end. Density of a fragment may delay union in fresh fractures but must not be considered as a sign of beginning non-union.

Results

Of 220 fresh fractures treated by my group in the years 1956, 1957, and 1958,

TABLE IV

DATA ON CARPAL-NAVICULAR FRACTURES

Case No.	Patient	Sex	Age at Time of Operation (*Years*)	Mid-carpal Dislocation	Side	Location			Type			Duration of Fracture before Operation	Duration of Immobilization after Operation (*Months*)	Degree of Function Dec. 1959 (*Percentage*)	Union
						Distal Third	Middle Third	Proximal Third	Horizontal Oblique	Transverse	Vertical Oblique				
1.	B. J.	M	22		R		X		X			2 yrs.	5	95	Yes
2.	D. H.	M	32		R		X			X		5 mos.	5	100	Yes
3.	F. L.	M	27		L			X		X		3 yrs.	3½	95	Yes
4.	F. A.	F	20		R		X				X	1½ yrs.	4	100	Yes
5.	G. J.	M	30		L		X			X		10 yrs.	4½	75	Yes
6.	K. K.	M	19		R		X			X		1 yr.	3½	95	Yes
7.	K. E.	M	27		L			X			X	2 yrs.	4	95	Yes
8.	K. E.	M	21		R		X			X		2 yrs.	4½	95	Yes
9.	K. J.	M	21		R		X			X		1½ yrs.	3½	80	No
10.	K. J.	M	24		L		X			X		2 yrs.	4	80	No
11.	K. H.	M	36	X	L		X			X		7 mos.	5½	90	Yes
12.	M. A.	M	25	X	R		X			X		1 mo.	7	95	Yes
13.	M. L.	M	40		R		X			X		8 mos.	4	100	Yes
14.	P. I.	F	25		L		X			X		2 yrs.	3½	100	Yes
15.	Q. K.	M	33	X	L		X			X		2½ mos.	3½	100	Yes
16.	R. F.	M	26		R		X			X		4 yrs.	5½	95	Yes
17.	S. L.	M	28		L	X				X		2 yrs.	5½	80	Yes
18.	S. J.	M	21		R		X			X		14 mos.	5	100	Yes
19.	S. A.	M	49		R		X			X		6 mos.	5	95	Yes
20.	W. J.	M	23		R		X				X	3½ yrs.	5	95	Yes
21.	W. L.	M	20		R		X			X		3 yrs.	6½	90	Yes
22.	W. A.	M	22		L		X			X		3 yrs.	4	100	Yes

six did not unite, making the incidence of bone union about 97 per cent. This agrees with Böhler's results in his 500 fresh navicular fractures treated during the years 1925 to 1952.

All twenty-seven navicular fractures with delayed treatment in the years 1956, 1957, and 1958, including those with traumatic cavities, that were treated by my group by prolonged plaster-cast fixation, united. The duration of delay varied between three weeks and three years, the average being six months. Plaster-cast fixation was usually a forearm cast—in some cases, a fist cast extending from the elbow to the tips of all fingers was used. Duration of immobilization varied from two to thirteen months, the average being five months.

OPERATIVE TREATMENT OF NON-UNION

Technique

With the patient under general anesthesia and a tourniquet applied to the arm, a longitudinal incision three to four centimeters in length is made on the volar aspect of the wrist. I have used this approach for twenty-two years in about ninety fractures. The volar approach to the navicular is easy and, in my opinion, it is superior to the dorsal or dorsoradial incision. From anatomical studies and from injection studies of the blood supply to the navicular, we know that the main blood supply enters the bone on its dorsal side (Figs. 1A and 1-B). None of these dorsal vessels and none of the vessels entering at the tuberosity is injured if the volar approach is used. From the cosmetic point of view, the volar incision is also preferable. Easily palpable landmarks for this incision are the radial styloid, the tendon of the flexor carpi radialis, and the volar aspect of the tuberosity of the navicular. A longitudinal incision three to four centimeters in length is placed just radial to the flexor carpi radialis tendon. The tendon is retracted to the ulnar side, and the incision is then carried down through the wrist capsule to the cleft of the non-union, which becomes clearly visible on marked dorsiflexion of the wrist. The fracture is usually in line with the tip of the radial styloid, which can easily be felt through the skin towels. The sclerotic bone ends are freshened with a small gouge, and a cavity is formed, extending well into the adjacent fragments (Fig. 7). Then from the patient's opposite iliac crest an oblong

piece of cancellous bone (about twenty by ten by ten millimeters) is taken to form a peg (ranging from twelve by four by four to fifteen by six by five millimeters) and small chips (about one to two millimeters). The peg is placed in the center of the preformed cavity, and the multiple small chips are firmly packed around it, completely obliterating the cavity. The process resembles that of a dentist filling a cavity in a tooth. The peg and the tightly packed chips serve as osteogenic material and also stabilize the fracture. Roentgenograms are made in two planes before and after filling of the cavity in order to determine the extent of the operative excavation of the fragments and to check the result of the filling up of the cavity. After removal of the pneumatic tourniquet, the capsule and skin are sutured, and a plaster cast is applied with the wrist in neutral position. The cast extends from the elbow to the terminal joint of the thumb and to the metacarpophalangeal joints of the other fingers. The cast is split immediately after the plaster has set throughout the whole volar side. Eight to ten days after the operation the stitches are removed, and a new cast is applied of the same type, except that it is not split and it is well molded at the palm. This cast should be very strong because it is worn for twelve to sixteen weeks after operation. It should be checked every week, or at least every other week, and must be replaced if it is defective or loose.

The operation is not indicated in the presence of a very small ulnar fragment. Patients with mid-carpal fracture-dislocation of the wrist should be operated on if, after a manipulative reduction, a cleft remains between the navicular fragments, suggesting interposition of ligaments.

Results

Table IV shows that for fifteen of the twenty-two patients reported here, on whom this procedure was performed, the time between the accident and the operation was one year or more. This indicates that a good number of these fractures were complete non-unions and that, therefore, the results are of special significance.

The follow-up of the twenty-two patients operated on by this technique in the Accident Hospital, Vienna XII, during the three years 1956, 1957, and 1958, showed bone union in twenty cases (90 per cent). For the remainder of my own patients and for those treated by this method elsewhere (a total of 120 cases is known to me) the average incidence of bone union was between 80 and 90 per cent. After healing of the fracture, strength of the grip returns to normal, and movements of the wrist become painless (Figs. 3 to 6). Most of the patients treated were laborers. The results achieved with the described technique have encouraged me to choose the subject of the fractured navicular for this presentation.

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Talipes Equinus Correction in Cerebral Palsy*

BY CARL D. MARTZ, M.D., INDIANAPOLIS, INDIANA

Several surgical procedures have been used in my practice for the correction of talipes equinus in cerebral palsy. None is considered uniformly successful, and each has special indications.

From 1944 to 1959, a total of 3,400 patients with cerebral palsy was seen in the Cerebral Palsy Clinic of the James Whitcomb Riley Hospital of Indiana University Medical Center. Only 147 of these patients received surgical correction of talipes equinus deformity. Recently, 126 of these patients were evaluated. Twenty-one other patients were not included because combined procedures had been performed which made it impossible to determine which procedure was responsible for the result.

There were 190 operations which included 111 Achilles-tendon lengthenings, nineteen musculotendinous recessions, two transections of the gastrocnemius muscle, eight lengthenings of the posterior tibial and peroneus longus tendons ("stirrup" tenotomies), twenty-one gastrocnemius-muscle denervations (Stoffel), twenty-three soleus-muscle denervations, and six tarsal arthrodeses.

Critical review of my data revealed that the descriptions of the initial clinical picture, of the surgical correction obtained, of the after-care, and of the growth and development patterns of the individual patients were inadequate to permit accurate evaluation of the results. This lack of basic information in records must not be too unusual in clinical studies of this disease, for there are many variables that influence the results, including individual variations of the patients, the accuracy of the observations recorded concerning the patients' conditions, the adequacy of the description of the operative procedures performed, and the evaluation of the end results [6]. Whether it will ever be possible to resolve these variables and to study comparable cases in controlled series is an open question. Future studies with agreement on the criteria for evaluation are now being planned.

In any study of patients with cerebral palsy the following factors should be analyzed: the pattern and distribution of the palsy, motor and mental age, muscle balance, stance, gait, and standard measurements of length, joint motions, and deformities. The period of neuromuscular maturation and skeletal growth during which the deformity was followed should be described, as well as the programs of training, bracing, and surgery.

RATIONALE OF TREATMENT

Because an accurate evaluation of the end results in the patients included in this study is not possible, a statistical analysis of the results would be of very limited value. Despite the limitations of this study, certain impressions have been gained concerning the nature of talipes equinus in cerebral palsy and the indications and timing for surgical treatment. In addition, certain premises have been established that will be tested in the future. It is the purpose of this presentation to record these impressions and premises in the hope that they will be of value to other surgeons who have to deal with this problem.

In the treatment of talipes equinus in cerebral palsy it is desirable to consider the nature of equinus deformity in terms of reflex physiology, faulty body mechanics as manifested by the patient's posture and motor activity, and the deforming contractures.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1960.

Once the nature of the equinus deformity and the mechanical needs of the patient are appreciated, appropriate surgical measures may be instituted, and effective and properly calibrated correction may be achieved.

The clinical findings in cerebral palsy often suggest retarded neuromuscular maturation or failure of development of the higher centers of nervous-system integration. The rate of maturation in the child with cerebral palsy is much slower than in the normal child and in many cases it ceases at a relatively primitive stage. Inhibitory and facilitatory functions of the central nervous system do not develop or are impaired, and afferent impulses cannot be controlled or suppressed properly by the patient [6, 8].

The most disabling feature of spastic paralysis is diminished voluntary control of muscle action. Spasticity seems to be a very useful substitute for voluntary muscle control and often disguises underlying muscle weakness [8].

As voluntary control is gained through maturation, experience, or practice, spasticity diminishes in cerebral palsy. By contrast, in multiple sclerosis there is an insidious increase in spasticity as voluntary muscle control is lost. Thus, the degree of spasticity seems inversely proportional to voluntary control. To diminish spasticity one must enhance voluntary control [8].

Diplegic rigidity may make so-called reflex standing possible, but this does not mean that patients showing this phenomenon are approaching the stage of independent standing and walking. Usually, with growth and maturation, the hypertonia in the extensor-muscle groups gradually diminishes, and the degree of hypertonia in the flexor muscles of the trunk, neck, and limbs increases [12,16]. An anthropoid posture, with hips and knees flexed and toe stance, develops, apparently as a result of weakness of the extensor muscles, the development of flexion contractures, and the effect of balancing reactions affecting the head, trunk, and arms.

Spasticity has a notorious tendency to cause myostatic contracture. As a result, even if voluntary control is acquired and spasticity lessens, the contracture remains to thwart newly gained function. The success of attempts to correct a contracture depends entirely on how much the natural elasticity of the contracted muscle has deteriorated.

In normal muscle, this elasticity depends primarily on the sarcolemma of the muscle fibers and the connective tissue that envelop the muscle fibers. In the connective tissue, the elements that presumably determine elasticity are the elastic fibers. Atrophy of muscle (as after neurectomy) changes this elasticity but little [1].

Contractility, on the other hand, is a function of the muscle fiber itself. When there is degeneration and replacement of the muscle parenchyma by fibrous tissue and scar formation, formidable changes in the elastic property of the muscle occur.

These changes are of greatest consequence in connection with the correction of contracture by mechanical means. If training and bracing fail to forestall or correct contracture, then surgery should be carried out to restore an adequate range of motion so that the learning of motor functions may proceed.

The common purpose of all surgery for the correction of talipes equinus in cerebral palsy is the elimination of an unyielding contracture that substantially limits joint function in a patient capable of utilizing and controlling an increased range of motion [8]. This elimination of contracture is done by lengthening of the musculotendinous mechanism. Persistent clonus, extensor-muscle thrust, or muscle imbalance may require selective denervation or tendon transfer. Postural decompensation may require osteotomy to correct bone deformity or arthrodesis to stabilize joints in older patients. Mixed patterns of spasticity and athetosis may also occasion fixed deformity and require surgical correction.

INDICATIONS FOR TREATMENT

The distinction between dynamic and contractural talipes equinus is the first consideration in the choosing of proper treatment.

Dynamic contractures respond to physical therapy, to bracing, and, to a limited degree, to some of the newer forms of medication. For persistent dynamic contractures, selective denervation is helpful; this gives selective loss of power and little or no loss of elasticity. Tendon transfer helps in imbalance due to dynamic contractures because it removes a deforming force and assists desired motion.

In fixed contracture, tendon lengthening is used. This reduces contractile power and corrects even extreme deformities. Some tendency to loss of correction due to progression of myostatic contractures has been noticed. Maintenance of correction throughout the period of rapid growth is especially important after tendon lengthening [14, 19].

Deformities about the hip and knee must receive careful consideration. Often, the equinus deformity is a compensatory deformity related to the deformity at the hip or knee. In the planning of treatment it is wise to start at the hips and proceed distally. Postural patterns set in motion by hip-flexion deformity produce knee flexion and in turn cause the patient to walk on the toes. The angle between the leg and the foot will often show that actually there is a true calcaneus deformity even though the patient is walking on the toes. This type of toe stance will correct itself automatically after the hips and knees are extended by training and bracing or by appropriate surgery [18].

A distinction between the role of the gastrocnemius and the soleus muscles in the production of the deformity must always be made [5, 7]. This can be accomplished by determining the amount of the equinus deformity with the knee flexed and with the knee extended. When equinus deformity decreases with flexion of the knee, the gastrocnemius muscle is at fault. When flexion of the knee does not alter the equinus deformity, the soleus muscle is responsible for the deformity. If a flexion deformity of the knee is corrected by placing of the foot in equinus position this flexion deformity may also be attributed to action of the gastrocnemius muscle.

When both equinus and varus deformities are present, the varus deformity necessitates outward rotation of the tibia about its long axis to bring the foot into a weight-bearing position. The rotation of the tibia takes place on the femur at the knee, and the knee tends to be extended. When talipes equinus is combined with valgus deformity, the reverse occurs; the tibia rotates inward, and the knee flexes to facilitate this inward rotation. A primary flexion contracture of the knee usually produces valgus position and abduction of the foot rather than varus position and adduction. One seldom sees a spastic equinovarus deformity associated with a flexed knee or a spastic equinovalgus deformity associated with an extended knee [26].

Lengthening procedures on the triceps surae mechanism vary in the amount of lengthening that they will accomplish. The surgeon must choose the procedure accordingly, matching the lengthening produced to the amount of deformity and to the expected bone growth.

The timing of the surgical procedure is extremely important because rapid bone growth will often nullify the effects of tendon lengthening [22]. It is pertinent to point out that the triceps surae passes over three of the epiphyseal plates of the lower extremity that account for more than 85 per cent of the growth in length of the extremity. The legs of the spastic children in this series elongated six inches when the children were between the ages of two and four years, and three inches when the children were between the ages of six and eight years. These rapid spurts in growth are in contrast to the average annual growth increment of one inch. They are the reason for avoiding surgical correction of equinus deformity until after the child has reached the age of four years and, preferably, until after he has reached age of eight years, if possible.

In children with dynamic equinus, the deformity does not increase much with growth if there is full activity during the growing years. The stretching caused by weight-bearing seems to compensate for the increasing length of the extremity.

Children with a contractural equinus deformity, on the other hand, tend to show greater deformity as growth proceeds.

The equinus deformity in some instances represents a combination of dynamic and contractural factors for which a combination of surgical procedures may be needed. Occasionally, a series of procedures must be carried out over the years in such a manner that different anatomical sites are chosen for each procedure to prevent excessive scarring [20].

The patterns of posture and gait change so much during infancy and early childhood that it is impossible at this age to predict with certainty a patient's potential power, performance, or deformity [16]. If tenotomy or neurectomy is carried out at this age it will occasionally be cause for regret. So often one attacks the problem of extensor-muscle thrust, when one should be more concerned with the weakness and the universal flexion pattern that the patient assumes as he fails to resist his increasing gravitational burden and changes his pattern of spastic muscle balance.

BRACING

The child's stage of motor development is a pertinent consideration in the planning of all forms of treatment. Encouragement should be given to crawling and creeping; head, trunk, and sitting balance; and standing and walking at the proper times. Braces, standing aids, and surgical treatment must be integrated into the treatment program according to the level of the child's development.

It is necessary to maintain the correction of equinus deformity during the period of rapid growth. In active children, night bracing may suffice without day bracing because of the stretching effect of weight-bearing. Whether night braces should be long or short depends on whether there is a simple contracture of the soleus muscle without knee flexion or whether there is equinus deformity combined with a knee-flexion contracture. Whenever possible, it is desirable to use a leg brace and to allow freedom of the remainder of the extremity. When there is a tendency to the development of deformities at the knee and hip, night bracing may be needed, with a toe-to-groin brace with a pelvic band as well, in some instances.

When day braces are indicated, they should be used early in the life of the child, for balance and confidence are dynamically acquired as the result of practice and experience; they cannot be taught. Control braces are accepted readily, becoming part of the patient's body image; they bring the attainment of balance, free stance, and gait within the child's comprehension and aid him to integrate postural and equilibratory reflexes into functionally useful patterns [11].

Rotational deformities are extremely important, and control braces for both day and night wear and for tibial or femoral segments or both are now available in a comfortable and effectual form.

EXERCISES

There is a place for passive stretching of spastic muscles. When the stretching is kept within the elastic limit of the muscles, no harm has been manifested clinically or by histological and electromyographic studies. Benefits do result when passive stretching is combined with bracing and active muscle training.

MOTIVATION OF PATIENT AND PARENTS

Cooperation of the patient and his family in carrying out the training program is of vital importance. The child's intelligence is not always the influential factor. The innate determination of the child to improve is the important matter, and this may be present in a mentally retarded child and absent in one of high intelligence [15]. All children who demonstrate a tremendous drive to walk and to help themselves should be given the benefits of surgical treatment. The realization of limited improvement must be borne in mind at all times. The tendency to blame

the children for lack of progress must be avoided; it is the problems presented by the disease that are to be blamed, not the child.

SURGICAL TREATMENT OF TALIPES EQUINUS

Achilles-Tendon Lengthening

Of the several methods available to correct equinus deformity, lengthening of the Achilles tendon has been used in the largest number of patients.

Subcutaneous lengthening of the Achilles tendon leaves much to be desired. Twenty-eight subcutaneous tendon lengthenings were done, and the average correction maintained over a period of years proved to be only 10 degrees. Correction by this technique is occasionally more complete than necessary — more often it is insufficient and accompanied by residual scarring [3]. It has often been used as a secondary procedure or as a matter of convenience. It has suffered from the fact that it was often employed in children in the young age group of zero to four years, in whom rapid bone growth was occurring and weight-bearing had not yet been started. I prefer to use training and bracing for this age group and have found only rare indications for surgical intervention at this stage.

Lengthening of the Achilles tendon by an open surgical procedure is used when both the gastrocnemius and the soleus muscles are involved in fixed contracture. This operation will give more correction than any other technique (as much as three to four inches). In eighty-three open Achilles-tendon lengthenings, the average correction maintained over a period of years proved to be 20 degrees, and this was the greatest correction maintained as the result of any techniques. It is worth mentioning in this connection that the release of the plantaris tendon should be complete and that often this small tendon and its muscle contribute remarkably to the equinus deformity.

The advantages of the open procedure include correction of the deformity, weakening of the spastic muscle, and reduced activity of the stretch reflex. There is some danger of overcorrecting the equinus deformity and producing a calcaneus deformity that may be very disabling [13].

Many of the recurrences of equinus deformity after tendon lengthening are related to growth, for it seems that the involved muscles in cerebral palsy do not grow so fast as the bones that they span [23]. This appears to be related to a loss of elasticity of the fascial muscle envelopes and to myostatic contracture within the muscle itself. Equinus deformity does not recur after this operation in patients past the age of fourteen years, and recurrence is rare after the age of six years in active, walking children.

Recession of the Gastrocnemius Muscle

Recession of the gastrocnemius muscle at the musculotendinous juncture was described by Vulpius and Stoffel in 1920, by Strayer in 1950, by Baker in 1954, and, recently, by Pollock in England [20]. This procedure allows lengthening with the maintenance of continuity of the triceps surae. Lengthening of from one to one and one-half inches can be achieved without scarring of the tendon sleeve, but the procedure does not adequately lengthen the soleus-muscle mass other than to free its dorsal fascia. In nineteen gastrocnemius-muscle recessions, an average correction of 10 degrees was maintained for over a period of one or more years. I have encountered some fibrosis at the site of operation in three patients and have observed loss of correction with the growth of the limb, which suggest that some elasticity had been lost in the muscle mass.

Transection of the Gastrocnemius Muscle

Transection of the gastrocnemius muscle was described by Silfverskiöld in 1924 and recently emphasized by Scaglietti [4] and Silver and Simon. The two heads of the muscle are divided just below their origins on the femur. The motor nerves to the gastrocnemius muscle may also be sectioned at the same time [4]. This sacri-

fices gastrocnemius-muscle strength, removes its contribution to the flow of afferent impulses, and, when neurectomy is added, leaves a muscle mass that undergoes atrophy without much fibrosis.

I employed this technique in two six-year-old children. After one year of follow-up, there was no appreciable maintenance of correction. Further trial is obviously needed before the technique can be properly evaluated. However, the soleus muscle has been the more common offender in equinus deformities in my experience and I have tried to save gastrocnemius-muscle power to protect the knee and allow for the possibility of hamstring transfers. A choice must be made, and the conditions at the hip, knee, and ankle must be carefully considered in making the decision. Sacrifice of the function of either the gastrocnemius or soleus muscle may be required, but rarely should both be sacrificed.

A somewhat similar operation consisting in circumferential release of the aponeurosis of the gastrocnemius muscle near its origin, as described by Green, is distinct in principle, since in this procedure the nerve supply and the action of the gastrocnemius muscle are preserved. A modest release of an equinus deformity caused by the action of the gastrocnemius muscle can be achieved by this procedure [13].

Section of the Posterior Tibial and Peroneus Longus Tendons

The tenotomy of Duncan, in which the posterior tibial and peroneus longus tendons are sectioned ("stirrup" tenotomy) within their sheaths above the malleoli, has been helpful in eight well selected patients in whom the equinus deformity was due to structural contracture of these muscles rather than of the triceps surae. During the postoperative immobilization for three to four weeks, the tendons restored their continuity. Equinus deformity affecting the front part of the foot was improved by this procedure. Section of the posterior tibial tendon alone at a site above the malleolus has been very helpful in correcting the internal rotation so commonly associated with equinus deformity in cerebral palsy and was combined with open Achilles-tendon lengthening on twenty-one occasions with consistent benefit.

Denervation of the Gastrocnemius Muscle

Selective denervation as described by Stoffel in 1913 has been very helpful in correcting persistent spasticity in the gastrocnemius muscle [17,28]. The denervated muscle mass remains elastic, and there is loss of power commensurate with the amount of denervation effected. Loss of gastrocnemius-muscle power may impair control of the knee, so the procedure should be chosen with care. Twenty-one selective denervations of the gastrocnemius muscle were done in the popliteal fossa according to the technique of Stoffel and Phelps. Persisting correction of the equinus deformity was not measurable but there was loss of gastrocnemius function with atrophy. Recurvatum of moderate severity (20 degrees) occurred in two patients who were subjected to hamstring transfers to the femur subsequent to gastrocnemius denervation.

Denervation of the Soleus Muscle

Denervation of the soleus muscle, as described by Eggers in 1952, proved helpful in twenty-three patients in whom spasticity and clonus were predominant in the soleus muscle [9,10]. This was recognized by checking for clonus and "the spastic reflex" with the knee flexed at 90 degrees with the patient in the prone posture. Dynamic thrust was eliminated, and there was relief of the snapping recurvatum deformity peculiar to the gait of the patient. Loss of strength after this procedure has been remarkable. Care must be taken in the selection of the patient and in the amount of denervation performed in order to avoid calcaneus deformity, which I have noted in two patients.

For the relief of overpowering spasticity causing dynamic equinus deformity

and clonus, neurectomy appears to be the procedure of choice. The deformity must be carefully evaluated before operation to select the appropriate portion of the triceps surae to be denervated and the proper amount of denervation to be done. Gross estimates of preoperative muscle analysis have been employed in this regard, as well as electrostimulation and selective section of the nerve fibers at the time of the surgical exposure.

Arthrodesis of the Tarsus

Triple arthrodesis of the tarsus has been used in six patients, ten to fourteen years of age. It is of value in simplifying the mechanics of the middle part of the foot and is an effective measure in correcting varus or valgus of the heel. In three of my patients, there was recurrence of valgus deformity; this seemed due more to the postural mechanics of knee-flexion deformity and resultant inward rotation of the tibia on the foot than to overflow of the peroneal group of muscles. The loss of flexibility detracted from the balancing ability of these three patients who were severely involved. The use of tarsal arthrodesis in the correction of severe equinus deformity was of little value in any of the six patients.

SUMMARY

In the treatment of equinus deformity in cerebral palsy, dynamic deformities should be distinguished from fixed structural contractures.

Spasticity and clonus can be relieved by selective neurectomy, whereas a fixed contracture requires lengthening of the musculotendinous mechanism.

The role of the gastrocnemius and soleus portions of the triceps surae in equinus deformity should be determined, and the appropriate muscle selected as the target for surgical treatment.

Postural deformities at the hip and knee must be carefully considered, and appropriate corrective procedures applied to them. Toe stance may be a compensatory mechanism secondary to postural deformities in the hip or knee and not a true equinus deformity.

The amount of musculotendinous lengthening needed for correction determines the site and technique selected for the surgical treatment of contractural equinus deformity.

The timing of the surgical treatment of equinus deformity is important. It should be avoided until after the child has reached the age of four years and, preferably, until after he has reached the age of eight years. If it is performed earlier in contractural equinus deformity, recurrence of deformity must be feared as the result of skeletal growth.

Healthy controversy may well continue with reference to the surgical procedures preferred. Of most importance is the accumulation of adequate data concerning patients accurately classified as to their problems, treatment, and end results. When such information is available, more rewarding end results can be achieved.

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DISCUSSION

Dr. William R. Duncan, Seattle, Washington: Dr. Martz has given an excellent review of the problem of talipes equinus in cerebral palsy, as well as his surgical experience with this condition. He has rightly emphasized the difficulty of objective evaluation of surgical results. The fact that he has performed surgical correction in only 5 per cent of his patients indicates a conservative approach to the problem. Attention has been directed to a number of interesting features of the biomechanics of talipes equinus as well as the related over-all problems that confront patients with this condition.

It should be emphasized that the primary disabling factor in spastic paralysis is paralysis—diminished voluntary control of muscle action. The spasticity, which we deem so objectionable, is actually a very useful substitution for loss of voluntary control. Without spasticity the average spastic diplegic would be as helpless as a patient with severe poliomyelitis. Brissaud put it well when he said that spasticity is the prosthesis of the paraplegic.

As voluntary control is gained through experience and practice, the spasticity diminishes. Such an exchange process is seen in reverse in multiple sclerosis, in which there is an insidious replacement with spasticity simultaneous with loss of voluntary control. Thus, the degree of spasticity is inversely proportional to voluntary control. To diminish spasticity one must enhance voluntary control. Although spasticity serves some useful purpose, it has a notorious tendency to cause myostatic contracture. As voluntary control is acquired, and as spasticity lessens, the contracture remains to thwart the newly gained function. If physical therapy and bracing fail to forestall or correct the contracture, it is then the responsibility of the surgeon to restore an adequate range of motion so that motor learning can proceed; this is often the case in spastic equinus deformity.

Of the several methods of surgical correction discussed by Dr. Martz, neurectomies, however discrete, and procedures that scar the muscle belly would seem least likely to further voluntary control. Tendon lengthening is the procedure of choice. For this procedure my associates and I

(Continued on page 797)

Osteochondritis Dissecans Following Legg-Calvé-Perthes Disease

A Report of One Case

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Osteochondritis dissecans of the femoral head occurring as a complication of Legg-Calvé-Perthes disease is quite rare. One patient with this combination of diseases has been under observation for the past thirteen years. The interesting problems associated with his treatment have prompted a review of the literature and the presentation of his case history.

Since Legg, Calvé, Perthes, and Waldenström, independently, and within a year of one another, described a disease that is characterized by degenerative changes in the capital femoral epiphysis of children and a self-limited course, much has been written about the clinical entity that now is commonly known as Legg-Calvé-Perthes disease. Despite this voluminous literature there has been little mention of osteochondritis dissecans of the femoral head as a sequel to Legg-Calvé-Perthes disease.

Magnin, in 1931, stated that no relationship between Legg-Calvé-Perthes disease and osteochondritis dissecans existed. He believed that the pathogenesis, pathology, and treatment of the two conditions were quite dissimilar. Haas, in 1937, described a boy, eight years old, with osteochondritis dissecans of both femoral heads, who, three years previously, had shown early signs of Legg-Calvé-Perthes disease involving both hip joints. In addition to Haas' report, there are several references in the literature to the possible association of osteochondritis dissecans of the femoral head with Legg-Calvé-Perthes disease [2,3,5,6,7,9,11,15,22,24].

During the course of Legg-Calvé-Perthes disease there characteristically occurs the so-called stage of fragmentation, which, roentgenographically, gives the appearance of separate fragments of bone within the femoral head. This stage usually lasts for three to eight months, and is followed by reossification of the rarified areas, consolidation, and, finally, the appearance of the normal trabecular pattern in the capital femoral epiphysis. If, after regeneration of the capital femoral epiphysis to its normal trabecular pattern, a fragment of bone appears to separate from the femoral head, it is reasonable to assume that osteochondritis dissecans has occurred as a complication of the previously existing Legg-Calvé-Perthes disease. As far as can be determined, only six such cases have been reported in the literature.

Five patients in the six reported cases were male. The sex in one case was not specified. The age at onset of Legg-Calvé-Perthes disease in these six patients ranged from five to fifteen years. The length of time required for osteochondritis dissecans to become manifested varied widely from the time that the diagnosis of Legg-Calvé-Perthes disease was first made to nineteen years after onset (Table I).

The symptoms were primarily those associated with any disease of the hip joint where incongruity of the articulating surfaces is present. Pain, limp, limitation of motion, and clicking were most often present.

Four of the patients received some form of protection from weight-bearing after the diagnosis of Legg-Calvé-Perthes disease was made, and one was continued on a similar program after osteochondritis dissecans was recognized. The patient reported by Freund was said to have had the combination of the two diseases when first seen, and was treated in a hip spica. None of the six previously

TABLE I

PREVIOUSLY REPORTED CASES OF OSTEOCHONDRITIS DISSECANS COMPLICATING LEGG-CALVÉ-PERTHES DISEASE

Author	Age of Patient When Legg-Calvé-Perthes Disease Was Found	Hip Involved	Sex	Treatment for Legg-Calvé-Perthes Disease	Age When Osteochondritis Dissecans Was Found	Hip Involved in Osteochondritis Dissecans	Treatment for Osteochondritis Dissecans	Results
Haas	5	Bilateral	M	Hip spica for 6 mos.; brace for 18 mos.	8	Bilateral	None	Painless hip with normal motion; no bone union at end of 3 yrs.
Freund	5	Bilateral	M	Hip spica for 3 mos.	5	Bilateral	Hip spica for 3 mos.	Painless hip with normal motion; no bone union; no follow-up stated
Evans	7	?	M	Bedrest and traction	12	Same	None	Reported as fair; no bone union; no follow-up stated
Ratliff	9	Left	M	Hip spica for 12 mos.	10	Left	Hip spica for 7 mos.	Slight ache with full range of motion; no bone healing; patient working as carpenter at age of 28 yrs.
Ratliff	7	Left	M	Recumbency on frame for 9 mos.	26	Left	None	Occasional pain with limited abduction; no bone union; patient able to do heavy work; no follow-up stated
Brailsford	15	?	?	?	21	Same	?	?

reported patients was explored surgically, and detailed information regarding the results of treatment is not available.

Gold, Green and Banks, Flashman and Ghormley, and Wiberg discussed the treatment of osteochondritis dissecans occurring in children. It is the opinion of these authors that rest and immobilization lead to healing in the majority of cases. Occasionally, healing does not take place; then, if dislocation of the fragment occurs or the symptoms persist or progress, surgery must be considered.

Many reports of the removal of bone fragments in osteochondritis dissecans of the hips of adults have been published [1,10,11,13,16,19,20,21,25]. To open the hip joint and to dislocate the head in order to visualize the defect is a major procedure,

FIG. 1

FIG. 2

Fig. 1: Roentgenogram of the left hip in September 1946, when the patient was ten years old, revealed typical changes of early Legg-Calvé-Perthes disease.

Fig. 2: Roentgenogram of the left hip in May 1947 revealed the resorption of bone in the femoral head to be well advanced and reossification to have begun. At this time the patient was allowed to be ambulatory with the protection of a Thomas ring-traction brace without weight-bearing.

FIG. 3

FIG. 4

Fig. 3: Roentgenogram of the left hip in October 1947 showed evidence of a localized fragment of bone on the superolateral aspect of the femoral head.

Fig. 4: Roentgenogram of the left hip in April 1949 showed increased density of the separated fragments, whereas the remainder of the head appeared to be composed of mature bone with normal trabeculations. The protecting brace was discontinued at this time, permitting full weight-bearing.

which, in itself, may lead to damage to the hip joint. Therefore, surgery is indicated only if symptoms persist, if it is believed that arthritis will develop rapidly if the fragment dislocates into the joint, or if there appears to be mechanical blockage of motion of the hip joint caused by the fragment.

D. B., a white boy, ten years old, was first seen at Elyria Memorial Hospital in September 1946, complaining of pain and stiffness in the left hip. These symptoms had been present intermittently for approximately eight months. The patient recalled falling on his left hip several weeks prior to the onset of symptoms.

On examination there was pain in the left hip on all motions. Flexion was 90 degrees, internal rotation was 0 degree, external rotation was 20 degrees, and abduction was 30 degrees. The roentgenogram at that time revealed the typical changes of early Legg-Calvé-Perthes disease (Fig. 1).

The patient was hospitalized and placed on complete bedrest with Buck's traction. This was

maintained for eight months. The patient was then allowed to walk with the protection of a Thomas ring-traction brace on the left lower extremity. The roentgenogram at this time showed resorption of bone in the femoral head to be well advanced and reossification to have begun (Fig. 2). In October 1947 a roentgenogram showed evidence for the first time of a localized fragment on the superolateral aspect of the left femoral head (Fig. 3). The separate fragment continued to show increased density, whereas in the remainder of the femoral head there developed the roentgenographic appearance of mature bone with trabeculations, as evident in the roentgenogram made in April 1949 (Fig. 4). The brace was discontinued in April 1949, and the patient was allowed full weight-bearing.

During the course of the next three years the patient's pain and stiffness increased, and the roentgenogram showed progressive changes typical of degenerative arthritis, with peripheral lipping, irregularity in the shape of the femoral head, and the previously noted separated fragment resting in a crater in the femoral head (Fig. 5).

FIG. 5

In December 1952, when the patient was sixteen years old, the left hip joint was exposed through a Smith-Petersen approach. When the head of the femur was dislocated it was found to be rough and irregular in contour with a crater on its superolateral aspect that contained several loose fragments of bone. These fragments were removed, and the head was remodeled to construct a smooth contour. To do this remodeling it was necessary to remove all of the articular cartilage, exposing cancellous bone over the whole of the femoral head. The femoral head, thus denuded of cartilage, was replaced in the acetabulum. The articular cartilage of the acetabulum was intact and was not disturbed. Histo-

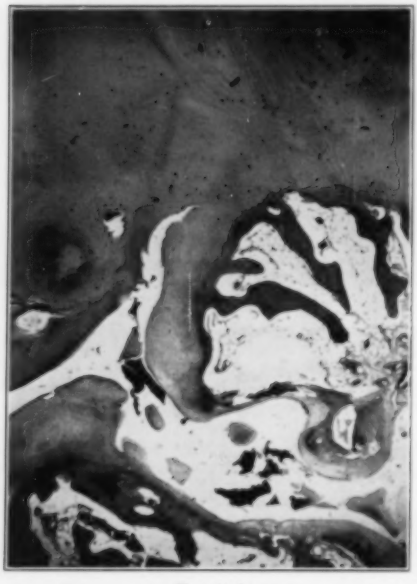

FIG. 6-A

FIG. 6-B

Fig. 5: Roentgenogram of the left hip in June 1952, when the patient was sixteen years old, revealed progressive changes typical of degenerative arthritis, with lipping and irregularity of contour of the femoral head in addition to the separated fragment.

Fig. 6-A: Photomicrograph of section of loose fragment removed from the hip, showing bone surrounded by articular cartilage (× 18).

Fig. 6-B: Photomicrograph showing necrotic and viable bone (× 200).

FIG. 7

FIG. 8

Fig. 7: Roentgenogram of the left hip in February 1953, showing the contour of the femoral head after surgery.

Fig. 8: Roentgenogram of the left hip in January 1959, when the patient was twenty-three years old, showing the condition of the femoral head six years after surgery.

logical examination of the removed tissue revealed several small fragments of cancellous bone covered on the articular side by cartilage. Fibrous tissue held the fragments loosely to the crater in the femoral head. There were irregular areas of necrotic bone with interspersed areas of viable bone (Figs. 6-A and 6-B).

After surgery the patient was immobilized in a hip spica for two weeks and then placed in balanced suspension with daily active exercises (Fig. 7). Ambulation with crutches with partial weight-bearing was begun two months after operation. Full weight-bearing was not permitted until five months after surgery.

After surgery the patient remained symptom-free, had no limp, and carried on a normal life. As a precautionary measure he was advised to abstain from participation in strenuous sports. The motions of the hip were flexion to 90 degrees, internal rotation to 10 degrees, external rotation to 20 degrees, and abduction to 45 degrees. There was no limb-length discrepancy. The pain, limp, and disability disappeared. A roentgenogram made in January 1959, when the patient was twenty-three years old, shows the appearance of the hip six years after surgery, with flattening of the femoral head and narrowing of the joint space on the superior aspect of the head (Fig. 8).

DISCUSSION

In this patient osteochondritis dissecans developed as a complication of Legg-Calvé-Perthes disease. It is not uncommon during the process of healing of Legg-Calvé-Perthes disease to observe in the roentgenogram a temporarily persistent localized area of increased bone density that has the appearance of osteochondritis dissecans. Under conservative treatment this area of bone almost invariably becomes revascularized and heals with the development of normal density and normal bone trabeculations without the development of incongruity of the joint surfaces. Surgery in these instances is inadvisable and unnecessary. In this particular patient, however, it became obvious that this necrotic portion of the femoral head would not become revascularized, and there was no evidence that it would be absorbed. As far as can be determined, this is the only reported case where surgery was necessary to remove such loose fragments. The indication for surgical treatment of this patient was failure of the bone fragments to heal and progression of symptoms despite conservative treatment. The prognosis for this hip must be guarded because degenerative changes are already present. Reconstructive surgery will probably be necessary at a later date, but during the seven years since the first operation the patient remained free of pain and continued to lead an essentially normal life.

NOTE: The author wishes to thank Dr. C. H. Heyman and Dr. C. H. Herndon for their assistance in the preparation of this report.

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Depressed Fractures of the Tibial Plateau

Treatment with Rigid Internal Fixation and Early Mobilization
A Preliminary Report

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It has been concluded by Hohl and Luck that the results of treatment for significantly displaced fractures of the tibial plateau depend not only on re-establishment of the normal horizontal plane of the articular surface of the tibia, perpendicular to the weight-bearing line, but also, and importantly, on the initiation of early motion in the knee. Their conclusions were based on a critical survey of a large series of cases and on the results of convincing experiments on the knees of monkeys. Their final conclusion was that early active motion is most important in obtaining optimum results in fractures of the tibial condyle.

It has frequently been observed by my confreres that if simple, stable fractures of the tibial plateau are treated merely by aspiration of the joint and non-weight-bearing on crutches the end results are excellent. This impression, in addition to my own observations, led me to devise a means of converting unstable major fractures of the tibial plateau into stable minor ones. By re-establishing stability in the fracture, early motion could be allowed in the knee. In accordance with this principle the fifteen severe fractures of the tibial plateau that are the basis of this report were treated by: (1) maximum correction of the deformity by open reduction; (2) firm internal fixation of the fragments; and (3) early knee motion. The internal fixation was so firm that immediate motion of the knee was possible.

This regimen of treatment has produced such good results with minimum hospitalization and convalescence that this preliminary report seems indicated. None of the fifteen patients so treated has been followed longer than six and a half years, so this report should not be considered as an end-result study. Conservative treatment of almost every degree has been advocated for these difficult fractures[1,2,3,4,12,14], but some authors[6,8,9,10,11,13,15] have advocated a more radical approach. No end-result study of fractures of the tibial plateau treated by internal fixation and immediate mobilization of the knee has been reported.

CASE MATERIAL

All the fractures of the tibial plateau seen by me during the six and a half years covered by this study were divided into two groups. In one group—approximately half of the total number—the patients had minimum deformity and were treated simply by aspiration and non-weight-bearing on crutches, with the knee freely mobile. In the other group in which there was significant deformity, an endeavor was made to reproduce the conditions in the first group using rigid internal fixation. There were fifteen patients with significant deformity. These comprise the material for this report. The fractures involved both condyles (the entire plateau) in five patients, the lateral condyle in seven patients, and the medial condyle in three patients. Only one of the fifteen patients was covered by workmen's compensation. None of the fractures resulted from automobile accidents despite the commonly used term, bumper fracture. In one instance the mechanism of one injury was similar to a bumper fracture, since the patient was gored by a bull. Two patients were injured in sports, the others in the course of their usual activities, such as housework and farm work. The common cause of the injury among the housewives was a fall due to standing on a chair. As a rule, the patients under thirty were injured by major trauma, whereas those over forty-five

sustained their fractures with relatively minor trauma. None of the patients, even those with minor fractures, were under the age of twenty-three. There were five female and ten male patients.

TREATMENT

The indications for operative treatment included any one of or a combination of the following deformities as shown by roentgenograms: (1) a vertical depression in the plateau of greater than five millimeters; (2) a horizontal displacement of the lateral or medial condyle of greater than one centimeter; (3) a valgus or varus deformity of the knee 5 or more degrees in excess of that of the uninjured knee; and (4) comminuted fractures involving both condyles regardless of displacement.

As already indicated, patients with fractures of lesser degree were treated without immobilization and were allowed to walk with crutches without weight-bearing; these are not included in this study.

The general principles guiding the treatment in these fifteen cases were: (1) to restore the normal plane of the tibial articular surface perpendicular to the weight-bearing line; (2) to maintain this initial reduction by strong and rigid coaptive and longitudinal internal fixation; (3) to assure eventual osseous support of the elevated plateau fragments by filling any residual cavities with bone grafts; and (4) to institute knee motion immediately after operation.

The operation is usually difficult. When the fracture is fully exposed the damage to the plateau is almost invariably much greater than indicated by the roentgenograms. Restoring of the fragments to their normal positions in an accurate or exact mosaic pattern is almost impossible at times. The depressed fragments occasionally must be elevated one-half to three-fourths of an inch or more and rotated from a perpendicular to a horizontal plane. In most cases a very considerable cavity was left under the articular plate after the fragments had been elevated. This was filled by supplementary bone to provide permanent support and nutrition for the reconstructed plateau. Comminution of the cortex of the lateral or medial condyle may be so extensive that there is insufficient intact cortex to hold the device used for fixation. It may then be necessary to reinforce the condyle with a horizontal metal support. The diversity and the complexity of these fractures preclude standardization of the technique. The surgeon must be prepared to modify the procedure according to the exigencies of the situation.

The procedure used for fractures of the medial condyle will be described here since it is the simplest and embodies the essential steps used in the treatment of all fractures of the tibial condyles. The skin incision must be long, extending from the upper pole of the patella to the mid-shaft of the tibia. The incision is placed halfway between the medial margin of the patella and the anterior margin of the medial collateral ligament and extends vertically downward almost to the level of the tibial articular surface, where it curves sharply posteriorly to cross the collateral ligament at its tibial insertion. The incision then curves anteriorly and distally along the shaft of the tibia to the middle of the diaphysis. The skin and subcutaneous fat on the convex side of the incision are reflected anteriorly to expose the medial capsule of the knee and the fracture of the anterior cortex of the tibia. The capsule and synovium are incised in a proximal direction in the line of the fracture, and the medial meniscus is removed. By gentle retraction of the fractured medial cortex, leaving the capsule and ligament attached to it, a curette can be inserted through the fracture line below the level of the depressed fragments. By use of this instrument as a lever, the depressed fragments are rotated and teased upward until they form the best possible semblance of the normal plateau. Springing of the knee in valgus may facilitate replacement of the fragments. An attempt should be made to reconstruct the plateau slightly higher than normal to allow for settling. A tibial bolt is drilled through the largest and most stable medial fragment and through the lateral cortex about one-half inch

below the articular cartilage. Through a lateral stab wound a washer and nut are tightened to the cortex. This incision is left open to permit further tightening later in the procedure. The cavity developed by elevating of the plateau fragments is now completely filled by packing it with soft cancellous bone obtained from the ilium or with bone from the tibial cortex or bone bank that has been fragmented in a blendor. The longitudinal strut plate is applied at this point. Much time, effort, and fitting may be saved if the plate has been bent prior to sterilization to conform to the contour of the medial condyle and tibial shaft as visualized on the roentgenogram. The strut plate must be long enough to permit three or four screws to be placed in the tibial shaft below the fracture. A short second (Table I, Case 2) plate bent to the horizontal contour of the condyle may be used to maintain a badly shattered plateau. If such a horizontal plate is used, the medial end of the bolt passes through one of the holes in this and through the proximal hole of the strut plate. The nuts are then tightened with considerable force by use of socket wrenches. The strut plate is next secured to the shaft of the tibia with three or four screws, care being taken to maintain the plateau at the normal height or preferably a little higher than normal so as to produce slight valgus. All of the plates are applied directly over the ligaments and periosteum, particular effort being made to minimize periosteal elevation. After the protruding ends of the bolt have been cut off, the suprapatellar pouch of the knee is ruptured to facilitate drainage of blood from the joint, and the wound is closed. A loose dressing is applied with no external support.

The procedure for fixation of the lateral condyle differs little from that described for the medial condyle. However, the presence of the origin of the anterior tibial muscle necessitates somewhat different placement of the strut plate. In the operations done earlier satisfactory lateral support for the transfixion bolt was provided by bending of the strut plate to bridge the condylar portion of the origin of the anterior tibial muscle. In operations done later the origin of this muscle was dissected off the periosteum, and the strut plate was bent to conform to the contour of the condyle. Both procedures proved to be satisfactory. The strut bridging the muscle origin gave good support and caused no difficulty, but its appearance in postoperative roentgenograms left much to be desired esthetically.

In comminuted fractures of the entire tibial plateau involving both condyles, the curved longitudinal incision is made either laterally or medially, depending on which condyle appears to be the most seriously fractured. A second transverse incision at about the level of the tibial tubercle extends from this incision to the opposite tibial condyle. Proximal and distal flaps are reflected to expose the fracture, the tibial shaft distally, and the joint capsule proximally. The proximal flap consists of skin and subcutaneous tissue. The thickness of the distal flap is dependent on whether the transverse incision extends laterally or medially. If the incision is lateral, the dissection is continued down directly to the ligaments and periosteum by division of the anterior tibial muscle and reflecting it laterally along with the skin and subcutaneous layers. If the incision is medial, the anatomy of this region is such that the dissection naturally follows the tissue plane between the subcutaneous and periosteal and ligamentous layers.

The dissection of the proximal flap is subcutaneous and extended just enough to permit a parapatellar incision to be made in the capsule and synovial membrane.

The tibial tubercle, frequently a separate fragment, may be retracted proximally by dividing of the capsule on both sides of the patella and patellar tendon. If it is not a separate fragment, the excellent exposure provided by this maneuver warrants its being osteotomized and then retracted. The tibial condyles, after removal of the menisci, are then reconstructed by assembling of the fragments and bolted firmly together so that they become a single proximal fragment. Strut plates are then attached to each end of the bolt on the lateral and medial sides of

the knee by second nuts and securely fixed to the tibial shaft by three or four screws in each side. If the screws of one side are directed posteriorly and those on the other side anteriorly, they will not be in contact with the plate on the opposite side and hence will pass through the opposite cortex unimpeded. Great care must be taken to maintain the tibial shaft in correct alignment with the reconstructed condyles while the strut plates are being attached to the bolt and shaft. The tibial tubercle may be reattached with either a long screw (Case 4) or by suturing (Case 13) to the soft parts.

The tibial transfixion bolt is considered to be an important element in the internal fixation of plateau fractures. First, it offers the means of applying and maintaining a strong coaptive force to what is frequently an explosion type of fracture. Secondly, it provides an excellent means, when supported longitudinally, of resisting perpendicular deforming forces. Mechanically, the tibial bolt is superior to a screw because it exerts a stronger coaptive force, its fixation in the opposite intact cortex is more certain, and it can be used with a strut plate on both sides if need be. The only advantage of a screw is that it eliminates the nuts, which may protrude subcutaneously. The stock tibial bolts used were usually five inches in length and one-eighth of an inch in diameter with recessed threads for one and a half inches on each end and one end pointed to facilitate drilling. The washers were usually seven-sixteenths of an inch in diameter, but, occasionally, with soft bone, washers three-quarters of an inch were used. Hexagonal nuts tightened by socket wrenches were far easier to employ than were the round nuts which must be tightened by pliers. All the metal employed was stainless steel from the same manufacturer, so that the formulae would be assuredly identical.

After operation, no support is provided to the leg and knee other than the bed with a folded sheet under the knee. Long periods with the knee in flexion over one or more pillows are not permitted. During the first few days after operation the leg may be supported by the nurse when the patient's position is changed. However, the patient is encouraged to move the leg himself as soon as possible. Beginning on the first postoperative day the surgeon or the resident, supporting the knee and the foot, passively moves the knee through its greatest tolerable range of flexion and extension three times a day for several minutes. During the maneuver the patient is encouraged to flex and extend the knee actively and he is also instructed in quadriceps exercises. If the patient fails to establish active motion by the third postoperative day, the leg is placed in a Thomas splint with a Pearson attachment with balanced suspension to permit him to exercise his knee voluntarily and practice active motion. Crutch-walking is encouraged as soon as muscular control of the knee is established. Throughout the convalescence, even after weight-bearing is allowed, active exercises are continued, with particular emphasis on stretching, if necessary, to recover the last few degrees of extension and flexion. The exercise regimen is planned, supervised, and frequently checked by the surgeon. The assistance of a physical therapist is helpful, but not essential.

The stage in the convalescence at which weight-bearing may be allowed is difficult to determine. The degree of healing demonstrated on the roentgenogram is inconclusive since the fracture lines, which are primarily in cancellous bone, are poorly depicted. The decision as to when weight-bearing may be allowed must be based on the opinion of the surgeon who performed the operation rather than on the appearance of the roentgenogram. The decision will depend on the degree of comminution of the fracture and the competence of the support for the plateau achieved by the bone graft and the metallic devices.

An attempt is made to control the amount of weight applied to the fractured leg on a quantitative basis. The patient is informed of the allowable load and is instructed to check this several times a day by placing the foot of the involved leg on a bathroom scales and pressing down to produce the recommended load. By doing this repeatedly he gets a clear mental image of the proper amount of weight to put on the leg. The usual initial amount of weight allowed is thirty-five

TABLE I

CRITERIA OF GRADING OF HOHL AND LUCK

Anatomic Grade	
Excellent	*Good*
(All of the following)	(Not more than one of the following)
1. Normal valgus within 5 degrees	1. Valgus of more than 5 degrees
2. Restoration of displacement within 3 millimeters	2. Minimal degenerative joint changes
3. No degenerative joint changes	
Fair	*Poor*
(Not more than two of the following)	(All of the following)
1. Valgus deformity of more than 10 degrees	1. Moderate or severe degenerative joint changes
2. Moderate degenerative joint changes	2. Lack of fracture reduction
3. Lack of fracture reduction	3. Valgus deformity of more than 10 degrees
Functional Grade	
Excellent	*Good*
(All of the following)	(Not more than one of the following)
1. Full extension of the knee	1. Lack of knee extension beyond 170 degrees
2. 120 degrees range of motion or more	2. Excessive lateral mobility
3. No abnormal abduction rocking	3. Mild aching each day
4. Normal strength and endurance	4. 90 degrees total range of motion
5. Occasional ache permissible	5. Weakness or easy fatigue
Fair	*Poor*
(Not more than two of the following)	(Three or more of the following)
1. Lack of knee extension more than 170 degrees	1. Lack of useful motion (less than 75 degrees)
2. 75 degrees range of motion	2. Unable to work
3. Discomfort for ordinary activity	3. Pain in all activity
4. Excessive lateral mobility	4. Excessive lateral mobility

pounds, which is little more than the weight of the leg, and this amount is increased as rapidly as the individual case warrants. In this series partial weight-bearing was allowed from one to four months after operation, the average time being two and a half months. The shortest period before complete weight-bearing was allowed was two and a half months, the longest was ten months, and the average was 4.8 months. No deformity as judged by clinical examination increased or developed under this regimen of weight-bearing.

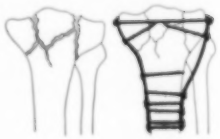
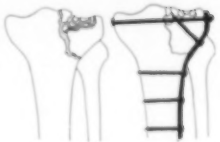
RESULTS

The standards of anatomical, roentgenographic, functional, and symptomatic results established by Hohl and Luck were used to grade the end results in this series of cases. Their chart outlining their criteria of grading is shown by Table I.

All patients included in this series were followed for from one to six and one-half years after operation. Each patient was examined by me, and accurate measurements of joint motion and deformity were made. All available preoperative and postoperative roentgenograms were reviewed, and the end-result roentgenograms were studied. Personal conversation with the patients determined their evaluation of their results. The findings of this end-result study are summarized in Table II*.

* Seven patients with similar fractures have been operated on since the reported study. These cases are too recent to be included, although in each case, with the exception of one, there will apparently be results equivalent to those reported. The one failure was an operation on a severely comminuted fracture of both tibial condyles in an aged woman with osteoporosis. The operation was performed in a strange hospital with inadequate facilities with the result that an unsatisfactory reduction and stabilization were obtained. This procedure was a mechanical failure, and knee fusion was required.

TABLE II

Case No.	Age at Fracture (*Years*)	Sex	Occupation	Type of Fracture	Operative Procedure	Time Required to Return to Regular Work (*Months*)	Length of Follow-up (*Years*)	Complications	Results (Graded According to Hohl and Luck) Anatomical	Results (Graded According to Hohl and Luck) Functional	Type of Motion	Time That Motion Was Begun after Operation (*Days*)	Weight-Bearing Type	Weight-Bearing Commencement after Operation (*Months*)	Comment
1	54	M	Farmer			6	6½	None	Excellent	Excellent	Passive Active Ambulation with crutches	3 10 14	Partial 1 crutch Complete	2½ 4 6	
2	71	F	Housewife			6	6	None	Excellent	Excellent	Passive Active Ambulation with crutches	1 14 21	Partial 1 crutch Complete	3 4 5	
3	65	F	Housewife			4	6	Bolt penetrated articular cartilage of normal condyle; removal and replacement; no sequelae	Excellent	Good	Passive Active Ambulation with crutches	1 3 10	Partial 1 crutch Complete	2½ 3 4	Subsequent intertrochanteric fracture of femur of same side without involvement of healed tibial fracture
4	46	M	Physician			4	4½	None	Excellent	Excellent	Passive Active Ambulation with crutches	1 21 8	Partial 1 crutch Complete	2¼ 3 5	Because patellar tendon insertion was a detached comminuted fragment, active extension delayed
5	37	M	Laborer			7	4¼	11 months after operation the plate and bolt were removed because of tenderness over a prominent bolt end	Good	Good	Passive Active Ambulation with crutches	1 3 7	Partial 1 crutch Complete	2 4 5	

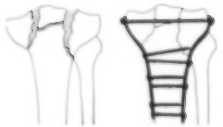
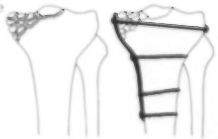
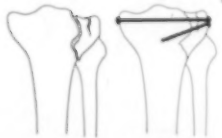
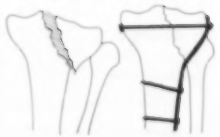
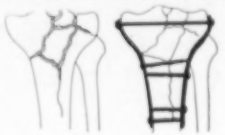
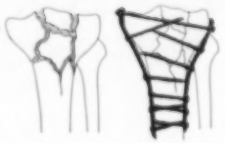
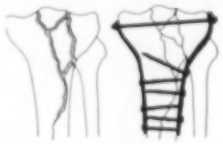
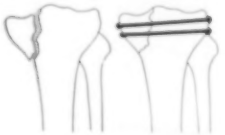
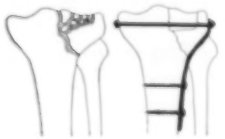
6	31	M	Janitor		4	4	None	Good	Good	Passive Active Ambulation with crutches	7 14 18	Partial 1 crutch Complete	2½ 3 4
7	25	M	Clerk		3	3½	None	Good	Good	Passive Active Ambulation with crutches	1 1 5	Partial 1 crutch Complete	1 2 2½
8	54	F	Housewife		(Difficult to evaluate; the patient also had a bimalleolar fracture of the same ankle and a Colles fracture and was also under psychiatric — institutional and shock — treatment	2½	Medial condyle was completely disorganized by the injury and could not be adequately reassembled at operation; postoperative roentgenograms suggested some absorption of the fragments	Fair	Fair	Passive Active Ambulation with crutches	14 28 75	Partial 1 crutch Complete	2½ 4 6½
9	57	M	Farmer		12	2½	None	Excellent	Excellent	Passive Active Ambulation with crutches	1 3 5	Partial 1 crutch Complete	2 3 4
10[a]	23	M	Laborer		4	2½	None	Good	Good	Passive Active Ambulation with crutches	1 3 10	Partial 1 crutch Complete	2½ 3 4

TABLE II (*Continued*)

Case No.	Age at Fracture (*Years*)	Sex	Occupation	Type of Fracture	Operative Procedure	Time Required to Return to Regular Work (*Months*)	Length of Follow-up (*Years*)	Complications	Results (Graded According to Hohl and Luck) Anatomical	Functional	Type of Motion	Time That Motion Was Begun after Operation (*Days*)	Weight-Bearing Type	Weight-Bearing Commencement after Operation (*Months*)	Comment
11	51	M	Farmer			6	2¼	None	Excellent	Excellent	Passive Active Ambulation with crutches	1 8 10	Partial 1 crutch Complete	2½ 3½ 4	Two years after first injury, patient sustained supracondylar fracture of femur of same side in fall of similar mechanism without involvement of healed tibial fracture **
12**	46	M	Lathe operator			13	2	Bolt and medial plate removed at five months because of tenderness and a sinus with serous discharge of 4 months' duration	Good	Good	Passive Active Ambulation with crutches	1 3 10	Partial 1 crutch Complete	2½ 3 10	
13	28	F	Clerk			3	1½	At 10 months there was removal of bolt and plate because of tenderness over the bolt	Good	Excellent	Passive Active Ambulation with crutches	1 3 12	Partial 1 crutch Complete	2½ 3½ 5	
14	26	M	Laborer			6	1¼	Tenderness at the medial end of the bolt was insufficient to warrant removal	Excellent	Excellent	Passive Active Ambulation with crutches	1 7 120 (multiple fractures, motorcycle accident)	Partial Complete	4 5	
15†	65	F	Housewife			4	1	Preinjury complaint of so-called arthritis in both knees; the swelling was relieved 6 months after operation by hydrocortone injection into the joint	Excellent	Excellent	Passive Active Ambulation with crutches	1 3 7	Partial 1 crutch Complete	2 2½ 3½	

* Recognized rupture of the medial collateral ligament not repaired at time of surgery, and the patient refused subsequent repair.
** Comminuted fracture of the patella of the same knee was resected three years prior to tibial-plateau fracture.
† Comminuted intercondylar fracture of the opposite femur two years prior to tibial-plateau fracture.

Fourteen of the fifteen patients were classified as having acceptable results by the Hohl and Luck standards. Rated anatomically, eight were *excellent*, six were *good*, and one was *fair*. Rated functionally, eight were *excellent*, six were *good*, and one was *fair*. All these patients, even the one rated as *unacceptable*, returned to their previous occupations with neither significant complaints nor material impediment in use. It is to be noted that six of these patients were engaged in heavy labor. The period of disability from regular work averaged five and a half months, with the extremes being three and thirteen months. The patient with thirteen months of disability was a compensation case; he had had a patellectomy for a comminuted fracture of the patella in the same knee three years previously. As anticipated, the longest disabilities were in those patients engaged in heavy labor.

Two of the patients sustained subsequent injuries to the same limb without effect on the healed tibial fracture; the patient in Case 3 had a intertrochanteric fracture, and the patient in Case 11 had an supracondylar fracture.

Each patient expressed the opinion that his result was satisfactory at the time of examination except for one patient (Case 8) who had severe psychiatric difficulties. Although she stated that her knee was satisfactory in response to a direct question, there was reason to doubt that she comprehended the actual meaning of the question. Among the remaining patients, the comments concerning their knees were frequently illustrative of how satisfactory the results actually were:

One cowboy (Case 1), who rode bucking broncos in rodeos, regretted that he could no longer sit on his heel while chatting with his cronies.

One refinery worker (Case 10), whose duties required him to use stairs and ladders eight hours a day, found his knee too unstable to play football, although he was on the company basketball team and he also played tennis.

All fifteen patients were able to lead with either leg in going up or down steps, although five were cautious on steps with high risers.

Two patients (Cases 6 and 13) were impeded in running.

Eight patients (Cases 2, 5, 6, 8, 11, 12, 13, and 14) stated that they had inconstant, transitory mild ache after long function. None had sharp or constant pain or symptoms indicative of post-traumatic arthritis. One patient (Case 15), who had had treatment for osteo-arthritis of her knee prior to the injury, had a recurrence of symptoms six months after the injury, but at one year after operation, she estimated her ache as being only moderate after long usage.

There was no complaint of knee instability except in the athlete who could no longer play football. At the follow-up examination, stability was tested in valgus, varus, anterior, and posterior directions. Slight instability in valgus was demonstrated in one knee (Case 14), and moderate instability in valgus was demonstrated in the knee of the refinery-worker athlete (Case 10) who had a recognized but unrepaired rupture of the medial collateral ligament. Also observed were slight instability in varus in one knee (Case 11), slight anterior instability in two knees (Cases 1 and 12), and slight posterior instability in one knee (Case 8). The examination in all instances confirmed the patients' statements that on the whole their knees were satisfactorily stable.

One inch of atrophy of the thigh of the affected leg usually persisted.

The amount of valgus or varus deformity was determined by measurement with a protractor and by comparison with the uninjured leg. Five knees demonstrated valgus greater than that of the opposite knee by 4 degrees in two knees (Cases 7 and 14) and by 5, 6, and 7 degrees, respectively, in the other three (Cases 12, 10, and 15). For the knee with 7 degrees of valgus there was no normal joint for comparison because the opposite leg had sustained a femoral supracondylar fracture previously. One knee (Case 8) had 5 degrees of varus. In none of the legs was the defect in alignment sufficient to make the appearance of the leg unacceptable.

FIG. 1-A

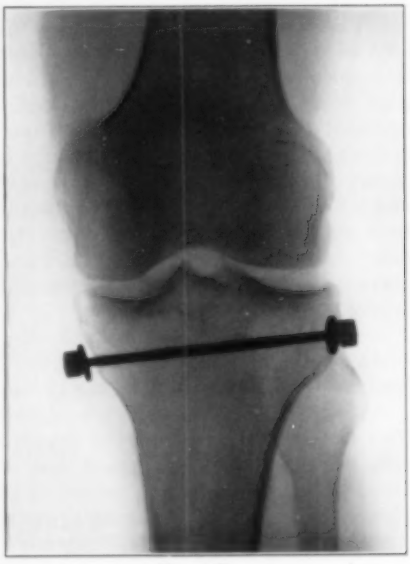


FIG. 1-B

Fig. 1-A: Case 7. A moderately unstable fracture. The preoperative roentgenogram shows a fracture of the lateral tibial condyle, markedly displaced laterally although with minimum depression.

Fig. 1-B: Eleven months after operation. The bolt, having changed the fracture from unstable to stable, permitted immediate motion in the knee.

FIG. 2-A

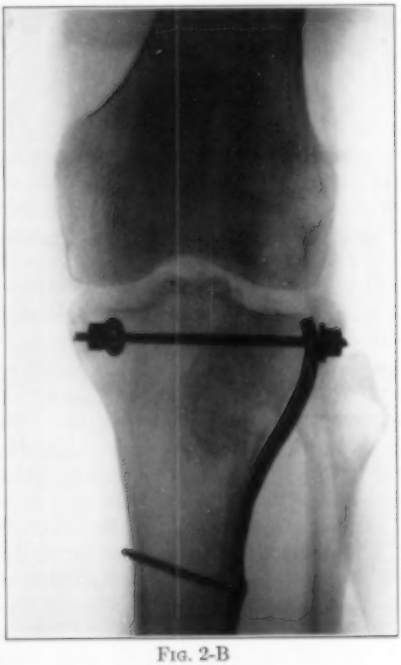


FIG. 2-B

Fig. 2-A: Case 10. A very unstable fracture. The preoperative roentgenogram shows a comminuted fracture of the lateral two-thirds of the tibial plateau. Note the marked central depression, comminution, and lateral displacement of the lateral condyle. The medial condyle is intact.

Fig. 2-B: Two and a half years after operation. The bolt and strut plate, having changed the fracture from very unstable to stable, permitted immediate motion in the knee.

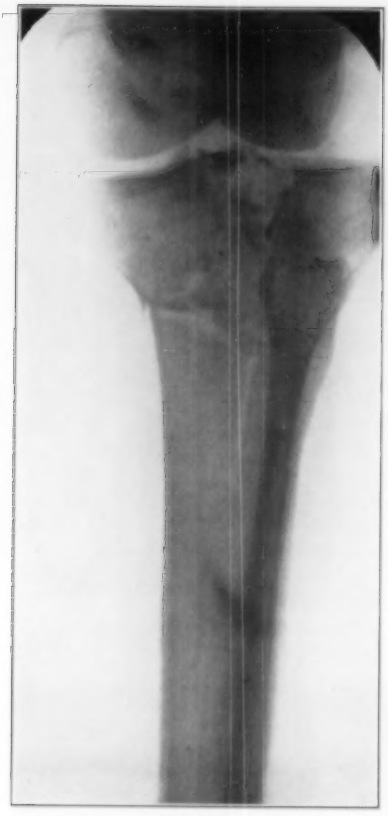


FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 4. A completely unstable fracture. The preoperative roentgenogram shows a comminuted fracture of the entire tibial plateau. Note the marked lateral displacement of the lateral condyle and the fracture extending distally in the shaft.

Fig. 3-B: Four and a half years after operation. The bolt and two strut plates, having changed the fracture from completely unstable to stable, permitted immediate motion in the knee. The lateral strut bridges the origin of the anterior tibial muscle.

Two housewives, both sixty-five years old, each had slight swelling in one knee at one (Case 15) and six (Case 3) years after operation, respectively. A third knee (Case 4) was reported to show afternoon swelling, although none was found at the time of the examination.

The range of motion for each of the involved knees was determined by comparison with the range of motion of the unaffected knee.

The average loss of flexion in the fifteen cases was 13 degrees. The greatest loss, which amounted to 30 degrees, occurred in a housewife seventy-one years old (Case 2). There was no loss of flexion in three knees (Cases 4, 7, and 10). The average loss of flexion in the six patients who were fifty-four or more years of age was 17.6 degrees, whereas in the nine patients under fifty-four years of age the average loss of motion was only 9.7 degrees.

Twelve cases had no loss of extension. The three other knees lost from 10 to 20 degrees of extension (Case 8, 13, and 15).

Nearly normal power was found in the thigh muscles of all the patients at follow-up except for the one (Case 15) who had been followed for only one year. By use of a rating of 5 as normal, this patient had extensor power of 3 and flexor power of 4. All other patients had ratings of 5 for extension and flexion except

FIG. 4-A

FIG 4-B

Preoperative roentgenograms showed severe comminution and depression of the medial plateau.

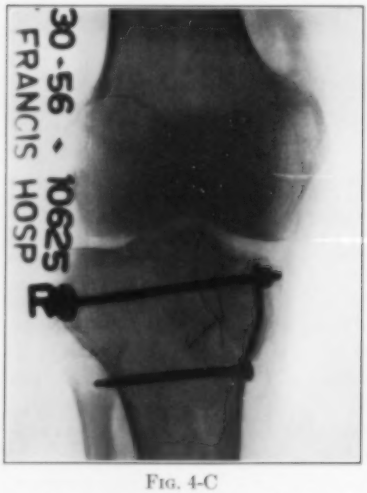


FIG. 4-C

FIG. 4-D

Postoperative roentgenograms showed inadequate reconstruction of the medial plateau.

for three (Cases 2, 8, and 12) who had extensor power rated as 4 and two (Cases 8 and 12) who had flexor power rated as 4. In no instance was the weakness sufficient to prevent the patient from leading with the fractured leg when going up stairs. Of particular interest was the knee (Case 12) on which a patellectomy had been performed previously. This joint lacked only 9 degrees of flexion as compared with the normal knee, and complete active extension was possible. Muscle power in flexion and extension was rated as 4.

Three patients (Cases 8, 12, and 15) had a slight limp that was not objectionable to the patient or to the physician.

In general, the appearance and function of these knees at follow-up were better than would have been expected from their appearance on the roentgenograms. This may indicate that in some of these knees traumatic arthritis will develop in the future.

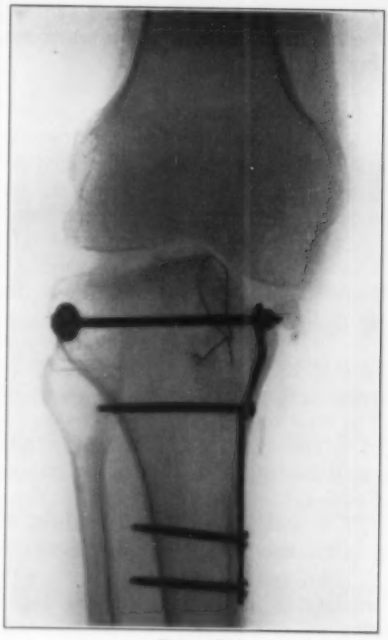


FIG. 4-E

Three years after operation there was loss of elevated plateau.

COMPLICATIONS

There were no operative infections, and no serious complications occurred.

In one instance (Case 3) the tibial bolt was inadvertently drilled through the articular cartilage of the normal condyle. This mistake was disclosed by a roentgenogram on the first postoperative day and was rectified on the next day by replacement of the bolt in its proper location without disturbing the longitudinal supporting plate. No untoward sequelae were noted.

The bolts, plates, and screws were removed from three patients (Cases 5, 12, and 13) because of tenderness over the protuding ends of the bolts. It probably would have sufficed to remove only the bolt and nuts, but all the metallic implants were taken out because they had served their purpose. These three patients were thin, with an inadequate subcutaneous layer of fat. In two of them there was no evidence of tissue reaction around the metal, and no bursa was found. In the other patient serous drainage developed one month after operation, with a small sinus that extended down to the bolt. This sinus promptly closed when the metal was removed five months after operation. Another patient (Case 6) complained of tenderness over the medial end of the bolt, but this was insufficient to warrant removal.

In one patient (Case 15) with generalized osteo-arthritis, an effusion in the injured knee developed six months after operation that was treated as it had been before operation by aspiration and intra-articular steroid injection.

Another patient (Case 8) had a severely comminuted and depressed fracture of the medial tibial condyle (Figs. 4-A and 4-B). An attempt to reconstruct this using a bone graft, bolt, plate screws, and wire loop failed (Figs. 4-C and 4-D). Subsequent roentgenograms (Fig. 4-E) showed complete collapse of the medial tibial plateau associated with some absorption and loss of bone substance. In retrospect it might have been preferable to treat this fracture by replacing the severely fragmented medial plateau with the patella as was done in Case 15. The functional result in this patient, a housewife with severe psychiatric problems, was difficult to evaluate. She was able to perform the household duties permitted by her psychiatric condition with no more discomfort than a "moderate" ache. She could also go up and down stairs leading with either leg and stated that her knee was always stable. There was no indication that the status of her knee function was changing at follow-up examination two and one-half years after operation. At that time her range of active motion was from 10 degrees of permanent flexion to 127 degrees of further flexion. The strength of knee extension was rated as 3 and that of flexion as 4. One-half an inch of atrophy of the thigh was noted along with a varus deformity of the knee amounting to 5 degrees. No anterior-posterior or medial-lateral instability was detectable. The anatomical result, as shown by the

roentgenograms made three years after operation, was entirely inconsistent with the function of this patient's knee and her symptoms. The result in this patient was rated as *fair*.

COMMENT

Hohl and Luck reported excellent end results in 93 per cent of the minor, stable plateau fractures (classified by them as "undisplaced") treated simply by immobilization. Since only 48 per cent of the fractures reported here were rated *excellent* both anatomically and functionally, it is apparent that the objective of the transforming of major displaced fractures to minor ones was not fully achieved. That the objective was approached, however, is suggested by the fact that 93 per cent of the results in these major unstable fractures have been acceptable up to the time of writing.

The bolt, plates, and screws used for fixation of these fractures of the tibial plateau have not posed any problems except for irritation of the skin and subcutaneous tissues in the thinner patients caused by the prominent ends of the bolt. The fixation provided by these metallic devices prevented significant recurrence of deformity in all cases, and the rigid fixation provided appears to have favored rapid healing. The impression gained from this study is that the more rigid the fixation, the better the result. In retrospect it would have been preferable in Cases 1, 7, 9, and 14, to use longitudinal strut plates and thus have assured more rigid fixation even though no significant deformity recurred in these knees.

Although at one time there was general reluctance to place metallic inserts in the neighborhood of joints, in other locations it has been demonstrated in recent years that this reluctance is not justified. Various types of nails and plates are used for intertrochanteric fractures of the hip; blade plates are used for supracondylar fractures of the femur; and several screws are placed around the ankle in fractures of the malleoli. The basic principle underlying these accepted methods of treatment is the same as that used for the stabilization of these fractures of the tibial condyles. There is relatively little soft tissue overlying the knee joint, and the extensive dissection necessary to insert these metallic devices, as well as the relatively large bulk of the devices themselves, might be expected to impair the blood supply to bone or overlying tissues. With the exception of the patient in Case 8, in whom some absorption of the bone fragment occurred after inadequate initial fixation, there was no evidence of impairment of blood supply.

The disadvantages and complications that may result from prolonged immobilization of joints, particularly the knees of older patients, are well known. In the plan of treatment proposed here, motion of the knee is resumed in the immediate postoperative period, and hence there is little opportunity for adhesions to develop either within the joint or in the capsule, as demonstrated by Hohl and Luck in monkeys. Since the motion in the joint is never really lost, little effort is required during convalescence to regain it. It is probable that the very early mobilization of the knee is as important in the end result as the reduction of the fracture because so many knees in which poor reduction is shown by roentgenograms have good function. Certainly, a good reduction of the fracture in addition to good range of motion should give the best results in the long run.

Some authors [5, 12] have emphasized the importance of immobilization of the knee to assure healing of ligament tears incidental to plateau fractures. It is obvious that by instituting early motion in the knees in this series there was no positive effort to protect the ligaments. Yet, instability did not play a significant role in the end results. Either the ligaments healed adequately despite knee motion, or the minor instabilities resulting from inadequate healing of the ligaments were not significant.

CONCLUSIONS

The results of this preliminary study indicate that the converting of an un-

stable fracture of the tibial plateau to a stable status by means of competent internal fixation permits early movement of the knee and contributes to improved functional and anatomical results.

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DISCUSSION

Talipes Equinus Correction in Cerebral Palsy

(Continued from page 776)

have used the three-level subcutaneous method in over 500 instances without regret. Although we have made no attempt to measure the amount of tendon, I would suspect that our lengthenings are considerably in excess of the criteria suggested by Dr. Martz. I wish to emphasize his remarks about the importance of distinguishing between talipes equinus of the front part of the foot and of the ankle. Equinus deformity of the front part of the foot responds well to lengthening of the posterior tibial and peroneus longus tendons, or, as he calls it, "stirrup" tenotomy, and poorly to surgery of the calf or heel cord. Lengthening of the calf structures in equinus deformity of the front part of the foot is certain to cause calcaneocavus deformity.

Dr. Martz suggests that surgery be delayed until the later part of the first decade, yet his case reports indicate that he has not always been of this opinion, as many patients were operated on in the first three years of their lives. From my experience, the time for surgery is when there is an unyielding contracture that is substantially impairing joint function in a child who appears capable of utilizing an increased range of motion.

One must not be too critical of the anthropoid posture of the diplegic, however offensive to orthopaedic concepts. It enables the beginning walker to correct displacements of balance by shifting his head, arm, and trunk—a function that his leg muscles are at the time unable to perform. Radical attack on the several deformities must await the establishment of adequate voluntary control.

A Case of Compression of Subclavian Vessels by a Fractured Clavicle Treated by Excision of the First Rib

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As a rule, fractures of the clavicle are insignificant injuries in children and require minimum treatment. In some instances, treatment is given more for the satisfaction of the parent than for the maintenance of position of the fracture. By contrast, in the adult, fractures of the clavicle are at times very disabling because of the tendency of these fractures to become comminuted and because of the associated early or late neurovascular injuries which sometimes occur. Watson-Jones stated that Sir Robert Peel, who created the police force of Great Britain in the first half of the nineteenth century, died of fracture of the clavicle. He was attended by Sir Benjamin Brodie, who wrote: "The haemorrhage itself was the consequence of the subclavian vein having been lacerated by the splinters of the fractured bone." Both Guillemin and Matry reported a case of laceration of the subclavian vein by long spicules from a fractured clavicle. Stone and Lord and Siffre and Aulong reported several cases of thrombosis of either the subclavian artery or vein occurring as a late sequel to malunion or non-union of the clavicle. Yates and Guest recorded the case of a patient in whom death occurred as a result of an embolism of the basilar artery, the embolism originating from a thrombus in the subclavian artery; an ununited fracture of the right clavicle in relation to the thrombosed artery was apparently the cause of the thrombosis. Autopsy showed extension of the thrombus from the subclavian artery to the origin of the common carotid artery. Traumatic aneurysm of the subclavian artery as a late complication of a healed fracture of the clavicle was reported both by Cayford and Tees and by Nelson. Injuries to the brachial plexus, occurring as early or late complications of fractures of the clavicle, were observed by Lotsch, Reid and Kennedy, and Van Vlack. The case reported here is an example of compression of the subclavian vessels without any appreciable effect on the nerves; the compression was successfully relieved by resection of the first rib through a posterior approach.

A white man, fifty-seven years old, came to the emergency room of the St. Louis City Hospital on March 15, 1959, complaining of pain in the region of the right shoulder and the right side of the chest. He said the pain, which was aggravated by deep breathing, was the result of a fall. Physical examination revealed a hematoma, of moderate size, over the right clavicle and an obvious fracture through the middle third of the clavicle. Examination of the right upper extremity was negative for neurovascular disorders. Roentgenograms revealed fractures of the right clavicle (Fig. 1) and the sixth and seventh ribs on the anterior axillary line.

After his chest was strapped and a figure-of-eight cast applied, the patient felt comfortable enough to go home. He was then given an appointment for a return visit to the orthopaedic clinic. However, two days later the patient returned to the emergency room, complaining of swelling of the right upper extremity. Immediate examination revealed prominence of the veins of the right upper extremity, cyanosis of the right hand, venous engorgement of the upper right side of the chest, and prominence of the veins of the left hand, without cyanosis or edema. The radial pulse on the right was normal in every respect. The cast appeared to be loose and well padded, with the axillary part of the cast trimmed low enough to eliminate any pressure on the neurovascular bundle. Despite this, the veins in the right upper extremity could not be completely emptied by raising the arm above the level of the heart.

The cast and strapping were taken off and the patient was admitted to the hospital, as an in-patient, for further study. Detailed physical examination did not reveal any other abnormalities,

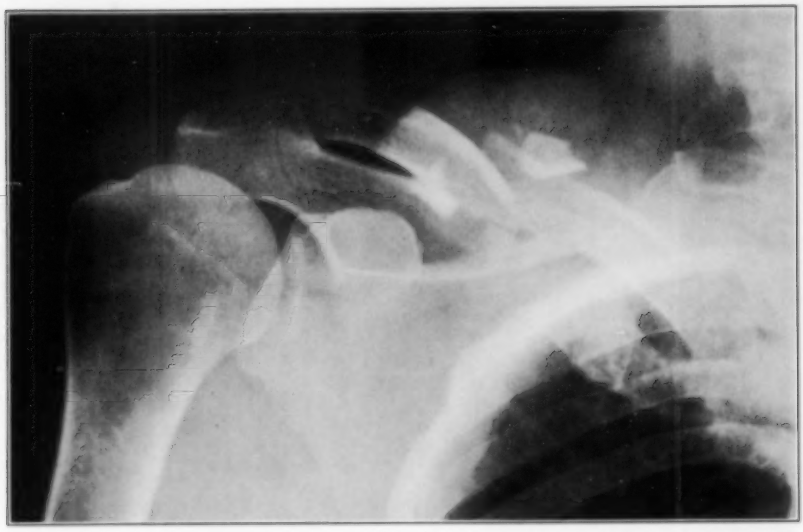

FIG. 1

Roentgenogram of the right clavicle, showing the comminuted displaced fracture and hematoma.

except some kyphosis of the thoracic spine. The patient was kept in bed, with his right upper extremity elevated by suspending it from an intravenous stand. Repeat roentgenograms showed the fractures of the clavicle and ribs to be essentially unchanged. The cardiac shadow was normal and the lung fields showed only a slight increase in bronchovascular markings. An attempt was made to obtain a venogram, using a 50 per cent solution of hypaque injected into the right median vein. However, the injection was discontinued because the patient had a pruritic reaction to the dye after only a few cubic centimeters of the solution had been injected. The venogram obtained was uninformative since the dye did not reach the site of the lesion.

An arteriovenous fistula was ruled out by absence of bruit or thrill and by the normal oxygen saturation of the arterial and venous blood in the arm (arterial blood, 15.4 milligrams per 100 cubic centimeters; venous blood, 9.5 milligrams per 100 cubic centimeters). Venous-pressure studies on both arms revealed no abnormality (right cubital vein, 78 millimeters; left, 76 millimeters of citrate solution). Even after one week of rest and elevation of the arm, the patient still had venous congestion and some edema. In addition, and of more significance, was the development of signs of intermittent compression of the subclavian artery. When the patient was standing with his arms dangling, the radial pulse was absent in the right arm, but was strong in the left. The pulse in the right upper extremity returned when the right arm was supported at the elbow. Adson's test was negative, but the right radial pulse disappeared when the shoulders were depressed or pulled back. A diagnosis of costoclavicular compression was made, and the consultant in thoracic surgery recommended excision of the first rib on the right side.

Operation was performed on April 10, 1959. After the patient was given an injection of sodium pentothal, endotracheal anesthesia was obtained with nitrous oxide and oxygen. With the patient in the left lateral decubitus position, a longitudinal incision was made parallel to the vertebral border of the right scapula, mid-way between it and the spine. The deep fascia, the trapezius, the rhomboidei, and the levator scapulae were incised in the line of the incision; the scapula was then retracted laterally. By blunt dissection anterior to the scapula, the thoracic cage was cleared as far laterally as possible without cutting the serratus anterior muscle. The insertion of the scalenus posterior muscle on the external surface of the second rib was then divided and retracted laterally, exposing the outer border of the first rib. The periosteum, together with the attachments of the scalenus medius, serratus anterior, and intercostal muscles, was then carefully stripped from the superior and inferior surfaces of the first rib. After dividing the insertion of the scalenus anterior, the inner border of the first rib was cleaned, care being taken not to injure the pleura, the vessels, and the nerves. The costoclavicular space was found to be constricted by reactive fibrous tissue and soft callus, which compressed the vessels against the first rib.

After completing the subperiosteal exposure of the first rib it was removed from the tip of the transverse process of the first thoracic vertebra to the costochrondral junction. When this had been accomplished, the axillary vessels and nerves were observed to have plenty of space and could be better visualized. They appeared to be normal in size, shape, and consistency. The wound was closed by suturing the scapular muscles, subcutaneous tissue, and skin. A No. 18 catheter was placed in the wound and brought out through a separate stab wound before closure.

FIG. 2

Roentgenogram of the right clavicle three months after operation, showing massive callus formation at the fracture site.

The patient tolerated the procedure well and the postoperative period was uneventful. The cyanosis and venous congestion disappeared and the radial pulse of the right arm was palpable and strong on the first postoperative day; on the third postoperative day the edema disappeared. The drain was removed seventy-two hours after operation. The patient was discharged home on the twelfth postoperative day.

The patient was subsequently followed in the fracture clinic. Seven weeks after fracture and four weeks after operation he was essentially asymptomatic and had full range of motion of the right shoulder. Roentgenograms made July 10, 1959, revealed complete healing of the fracture of the clavicle. At that time there was no evidence of neurovascular disorder, but a visible and palpable mass on the clavicle due to excessive callus was still present (Fig. 2).

DISCUSSION

Since prominent veins were also observed in the left hand and forearm, the first question that would arise would be whether the patient had intermittent venous congestion in his hand and forearm before injury. Careful questioning did not reveal any such history. The intermittent compression of subclavian vessels, which is sometimes observed in normal persons after the age of fifty because of their faulty posture, was investigated by Sampson and associates. They stated that with high thoracic kyphosis or a slouched posture the clavicle is lowered but it is also moved from the ribs, thus preventing encroachment on the subclavicular space. Since our patient has such a posture he is, if anything, less liable to develop such compression or effort thrombosis.

Was the figure-of-eight cast responsible for venous obstruction? The cast was well padded and loose; the axillae were completely free. Furthermore, the fact that the congestion, the cyanosis, and the venous engorgement did not disappear after removal of the cast makes this an unlikely cause of the obstruction.

The sensitivity to hypaque prevented us from demonstrating the existence of any obstruction to the subclavian vein. However, compression of the vessels by the reactive fibrosis and soft callus was visualized at surgery.

In our opinion the venous congestion in this patient was initially due to the displacement of comminuted fragments of the clavicle and to the hematoma. Because it was thought at first that absorption of the hematoma would reduce the venous compression, surgery was delayed for three weeks. However, excessive

callus formation, presumably due to inadequate immobilization, perpetuated the vascular compression. Early open reduction and internal fixation should prevent such a complication; but this may be difficult to accomplish in the presence of marked comminution and may be followed by non-union. Partial excision of the clavicle decompresses the vessels and makes the rehabilitation of the patient much easier and quicker since it eliminates the need for the fracture to heal. This operation also provides excellent exposure for exploration and reconstruction of major vessels.

Although the results of excision of the clavicle are usually satisfactory, occasionally after this procedure patients continue to complain of pain in the shoulder region. In addition, this operation leaves an unsightly scar in a very obvious area, especially in women, and it removes an important protective structure over an area that contains important neurovascular structures. Excision of the first rib is an alternative approach to relieve the vascular compression in the costoclavicular space. This is an easy operation and does not have the disadvantages just mentioned. However, if extensive vascular surgery or neurolysis is contemplated, the posterior approach does not give adequate exposure and the more direct approach through the fracture site should be used.

SUMMARY

A case of compression of the subclavian vessels due to fracture of a clavicle is reported, and the pertinent literature is reviewed. Treatment by resection of the first rib, as described, gave a satisfactory result. The advantages and disadvantages of partial excision of the first rib *versus* clavicle are discussed.

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Fibrosarcoma Arising at the Site of Bone Infarcts

A Report of Two Cases

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Two patients with multiple, idiopathic bone infarcts and fibrosarcoma at the site of one of the infarcts were studied at the University Hospitals.

Although the clinical, pathological, and experimental aspects of lesions resulting from the interruption of the blood supply to some areas about the metaphysis of long bones were extensively discussed in the literature [1,3,6,12,13,15,16] we have not encountered in our review of the literature the report of a case of malignant tumor arising in the area of a bone infarct. In our opinion, the following cases represent examples of such a condition. Johnson referred to the occasional development of bone sarcomata in the actively proliferating margin of a bone infarct as well as an old osteomyelitic scar or an old unresolved callus. Phemister is reported to have seen a case of sarcoma which arose from the margin of a bone infarct [10].

Case 1. A. J. V., a white, punch-press operator, fifty-three years old, noted the insidious onset of a dull aching pain in the upper aspect of the left leg one month prior to admission. The pain was worse at night and was aggravated by activity. There was no preceding trauma or associated fever or chills. The patient's past history was not remarkable. He had always done factory work, and he specifically denied any exposure to compressed air. Physical examination revealed no abnormality except for the proximal end of the left tibia. At this site there was mild diffuse swelling over the anteromedial aspect, together with slight tenderness and increased heat.

Laboratory studies, including the usual blood studies, were within normal limits except for a corrected sedimentation rate of 30 millimeters per hour (Wintrobe). Roentgenographic examination of the chest and skeleton was normal with the exception of changes noted in both lower extremities (Figs. 1-A, 1-B, 1-C, and 1-D). There were irregular lacelike areas of increased density of varying extent in the central cancellous portions of the distal metaphyses of both femora and the proximal and distal metaphyses of both tibiae. In addition, the proximal end of the left tibia revealed several discrete areas of osteolysis dispersed throughout the sclerotic regions and an adjacent periosteal reaction on the lateral side of the tibia. No evidence of degenerative arthritis was noted in any of the major joints.

Frozen sections of tissue obtained at open biopsy of the lesion in the proximal end of the left tibia on July 21, 1955, were interpreted as showing fibrosarcoma of bone. A mid-thigh amputation was performed at that time with a pneumatic tourniquet applied to the upper portion of the thigh prior to biopsy and not released until after the amputation was completed.

Examination of the amputated extremity after it had been cut in the sagittal plane revealed in the distal end of the femur and in both ends of the tibia, small, well demarcated, yellowish white areas in the cancellous bone with the gross appearance typical of bone infarcts. A much larger lesion, measuring ten centimeters by two centimeters, was present in the proximal end of the tibia. It involved the entire medullary cavity and had eroded through the thinned-out lateral cortex in an area two centimeters in diameter. This latter lesion in the proximal portion of the tibia was made up almost entirely of grayish pink soft tissue which extended for a distance of five centimeters into the muscle overlying the defect in the cortex. Yellowish white mottled tissue, similar to that in the distal portions of the femur and tibia, was present throughout the central portion of the tumor. There was an area of fresh hemorrhage in the central portion of the tumor corresponding to the site of the previous biopsy.

Microscopic sections from the proximal portion of the tibia (Fig. 1-E) revealed a large number of necrotic bone trabeculae with irregular borders. In between these fragments of dead bone and fatty bone marrow there was considerable fibrous tissue showing hyalinization and some calcification, as is usually seen in bone infarcts. Interspersed between these areas of infarction were relatively normal trabeculae of viable cancellous bone. In other areas, the osseous elements were disintegrated and destroyed by the ingrowth of a highly cellular tumor. In some fields, the neoplastic tissue was found to be in contact with necrotic, irregular bone trabeculae that constituted the infarct.

FIG. 1-A FIG. 1-B

Fig. 1-A: Case 1. Anteroposterior roentgenograms of the left knee with the irregular lacelike areas of increased density of bone infarcts in the distal portion of the femur and proximal portion of the tibia. In addition, the proximal end of the tibia has several areas of discrete osteolysis dispersed throughout the infarct. There is adjacent periosteal reaction in the same area.

Fig. 1-B: Lateral roentgenogram of the left knee.

FIG. 1-C FIG. 1-D

Fig. 1-C: Lateral roentgenogram of the right knee demonstrating bone infarcts in the distal portion of the femur and proximal portion of the tibia.

Fig. 1-D: Lateral roentgenogram of the right ankle showing a typical bone infarct in the distal portion of the tibia.

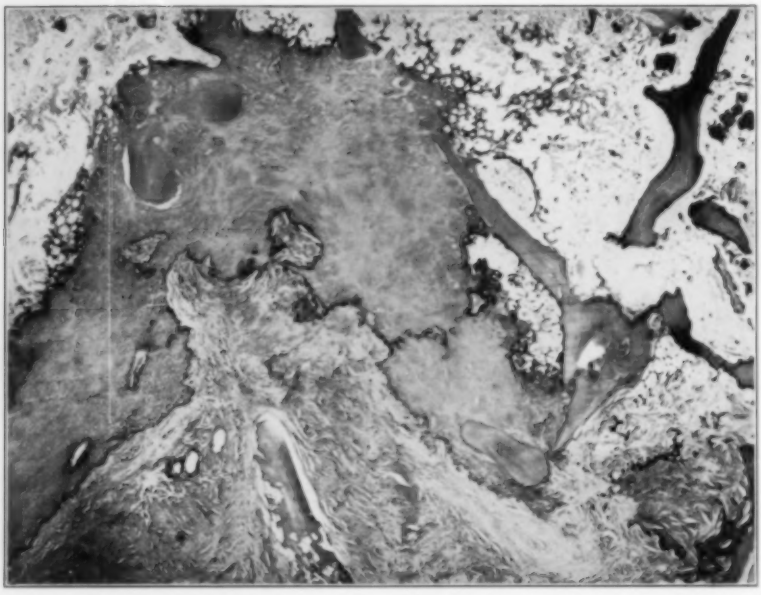

FIG. 1-E

Low-power microscopic view from the proximal end of the left tibia demonstrating necrotic bone trabeculae, considerable fibrosis, hyalinization, and some calcification as is usually seen in bone infarcts.

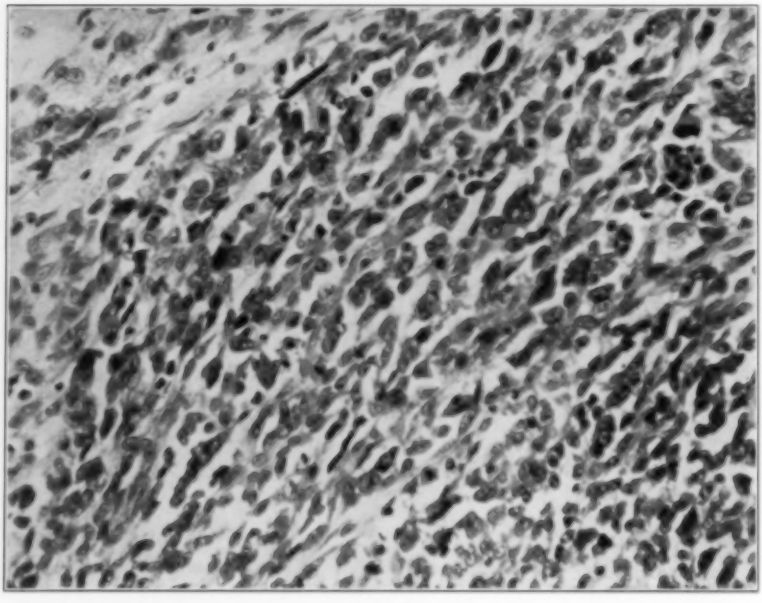

FIG. 1-F

High-power microscopic view of the highly cellular and pleomorphic fibrosarcoma tissue. The nuclei seen show marked irregularity in size, shape, and staining properties. Many mitotic figures are present.

FIG. 2-A FIG. 2-B

Fig. 2-A: Case 2. Anteroposterior roentgenogram of the right knee made on October 15, 1954, with the irregular lacelike areas of increased density of bone infarcts in the distal portion of the femur and proximal portion of the tibia. In the superior aspect of the tibial infarct an area of osteolysis is present which extends into the epiphysis.

Fig. 2-B: Lateral roentgenogram of the right knee made on October 15, 1954. The osteolytic process in the proximal portion of the tibia has not penetrated the anterior cortex.

The tumor tissue was highly cellular and pleomorphic (Fig. 1-F). In the more differentiated areas, the cells appeared to be elongated and in many areas dense collagen was visible. The nuclei of these cells showed marked irregularity in size, shape, and staining properties. There were many atypical forms and mitotic figures. No evidence of osteoid formation by the sarcomatous cells was seen in any of the ten specimens taken from different areas of the tumor. The diagnosis was fibrosarcoma.

Two months after amputation, the patient complained of constant back pain, and a roentgenogram of the chest seven months after operation revealed multiple metastatic nodules throughout both lung fields. The patient died on May 7, 1956, ten months after amputation, with widespread metastases. Permission for autopsy could not be obtained.

CASE 2. M. D., a Negro laborer, fifty-eight years old, first came under our care in September 1954, at which time he complained of pain in the region of his right knee which had developed insidiously without related trauma or infection. In October 1953, the patient had sustained a sudden left hemiplegia which left a permanent paresis of the left upper and lower extremities. The only other significant past medical history was that of syphilis contracted twenty years previously, which had been treated with injections at a clinic for one year. This man had done only manual labor; he specifically denied having worked under compressed air.

Physical examination of the patient revealed the typical findings of left hemiplegia and, in addition, localized tenderness over the upper anterior aspect of the right tibia. There was no swelling or increased heat in this region, and no changes were present in the right knee joint. Routine laboratory studies, which included serum calcium, phosphorus, and alkaline-phosphatase determination, were all within normal limits. Serological tests for syphilis were negative. Roentgenographic examination of the patient's entire skeleton and chest was within normal limits with the exception of symmetrical changes at the knees (Figs. 2-A, 2-B, 2-C, and 2-D). Here there were multiple irregular densities in the distal ends of the femora and proximal ends of the tibiae. In addition, a circular area of decreased density approximately two centimeters in diameter was detected in the anterior aspect of the proximal portion of the right tibia with no associated periosteal reaction.

Consent for biopsy of the osteolytic lesion of the right tibia was not obtained until April 14, 1955. At operation a small window was cut in the anterolateral cortex of the upper portion of the right tibia and a large cavity was exposed. This contained a white, fatty, fibrous tissue, which on

FIG. 2-C FIG. 2-D

Fig. 2-C: Lateral roentgenogram of the left knee made on October 15, 1954, demonstrating a large infarct in the proximal portion of the tibia and minor changes in the distal portion of the femur.

Fig. 2-D: Anteroposterior roentgenogram of the right knee made on February 10, 1956, after a total of 4,470 r was administered to this area, revealing extensive progression of the osteolytic lesion from that in Fig. 2-A.

microscopic examination was found to consist of masses of regular cells of bizarre appearance along with foci of necrosis and fibrosis. The cells were of the mesenchymal type with indistinct cell borders, acidophilic cytoplasm, and large spindle-shaped nuclei with rounded ends. Atypical mitoses were frequent. Bizarre cell forms, including cells with giant nuclei and multinucleated cells, were present in moderate numbers. The nuclei were often arranged in palisaded fashion. Numerous slitlike spaces were present, some being filled with red blood cells. There was no formation of osteoid by the sarcomatous cells. In one section, periosteum and cortical bone were invaded by neoplastic cells. This undifferentiated malignant mesenchymal tumor was considered to be a fibrosarcoma.

In view of the findings in the biopsy specimen immediate high thigh amputation was recommended, but the patient refused. Roentgen therapy was then instituted, and a total of 4,470 r was administered to the tumor area. Roentgenographic examination of the right tibia in February 1956, revealed extensive progression of the osteolytic lesion, but there were no changes noted in the irregular areas of increased density in this same region. Roentgenograms of the skeleton and chest failed to reveal evidence of metastasis. Because of increasing pain about the right knee and severe soft-tissue changes from the irradiation, the patient consented to a high thigh amputation, which was performed on February 17, 1956.

The macroscopic examination of the amputated extremity showed moderate swelling at and below the knee anteriorly with no significant gross abnormality at the site of amputation. On sagittal section of the amputated extremity (Fig. 2-E), in the area of swelling below the knee, a soft friable brownish red tumor was exposed that extended outward from the tibia to the skin. The bone of the anterior upper surface of the tibia was eroded by tumor and the tumor had extended up to but not into the knee joint and down the shaft for a distance of ten centimeters. The joint space was not invaded and the synovial lining of the knee was smooth and glistening. In the cancellous bone immediately below the tumor tissue there was an irregular area of yellowish white tissue, 2.5 centimeters long, which was separate and distinct from the surrounding marrow. A similar, longer area of whorled yellowish white tissue was present in the marrow of the lower metaphysis of the femur. The appearance of these areas was consistent with that of a bone infarct.

Histological study revealed the predominant cell was spindle shaped with an elongated

nucleus with the same characteristics that were found in the tissue by biopsy. (Fig. 2-F). Many sections were examined, but no osteoid was found. The diagnosis of fibrosarcoma was confirmed.

The patient made an uneventful postoperative recovery, and a follow-up report from the patient on November 20, 1958, two years and nine months after amputation, revealed that he was getting along quite well and had no symptoms referable to the remaining bone lesion.

FIG. 2-E

Sagittal section of the amputated right knee demonstrating the tumor erupting from the proximal portion of the tibia up to the knee joint and out to the skin. A remnant of the tibial infarct is seen just inferior to the tumor, and the distal femoral infarct can be identified by the white lines in the marrow in the metaphyseal area.

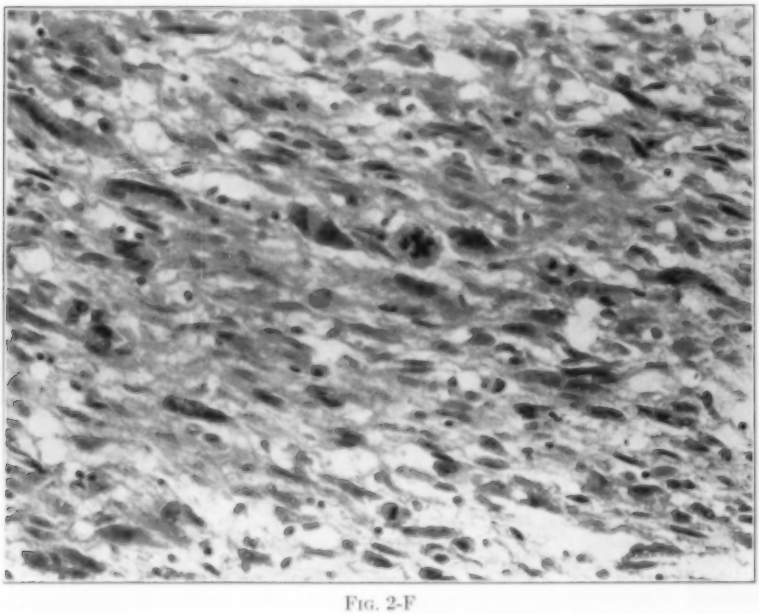

FIG. 2-F

High-power microscopic view of the fibrosarcoma tumor tissue reveals a highly cellular, pleomorphic tumor. There are many bizarre cell forms and numerous mitoses.

DISCUSSION

It is an accepted fact that the pathogenesis of caisson disease, first described by Paul Bert in 1871, is related to the formation of bubbles of nitrogen in the blood and tissues. These bubbles form when the atmospheric pressure is reduced sufficiently to make the blood and tissues supersaturated with nitrogen before the lungs can eliminate the excess nitrogen. The bone lesion is the result of nutritional interference caused either by nitrogen embolism in a main nutrient vessel or by occlusion of the vessel by extensive pressure from nitrogen bubbles in the surrounding tissues. The articular lesion in this disease is a degenerative arthritis which results from absorption, collapse, and new-bone formation in the epiphyseal region. The long bones are the favored areas for the formation of bone infarcts. The membranous bones are seldom affected, probably because of the predominance of red marrow in bones of this type, which implies a better blood supply less likely to be occluded.

The relation between multiple bone infarcts and caisson disease has been well established. Bassoe in 1913 made a careful study of nine patients with late manifestations of decompression disease. In 1940 Coley and Moore reviewed the literature and described the typical roentgenographic findings in two patients having bone and joint lesions associated with caisson disease. These authors described the typical roentgenographic changes as multiple areas of increased density that are surrounded by a thin band of dense bone and located within normal cancellous bone. The lesions are usually seen in the metaphyseal region. When changes occur in the epiphysis, they are associated with degenerative arthritis in the adjacent joint. Changes in the cortex of bone are very rare. The late osseous manifestations of caisson disease are usually asymptomatic and are often encountered as incidental findings in the course of a roentgenographic examination or because of symptoms referable to late arthritic changes.

Cases of multiple bone infarcts have been studied by numerous authors. In 1944 Taylor published the first large series, reporting fifty-four patients with bone infarcts, thirteen of whom had worked under compressed air for varying periods of time. He was unable to find an adequate explanation for the bone and joint lesions in the other forty-one patients. The extra-articular changes that he described were found chiefly within the medulla in the metaphyses of long bones. The roentgenographic appearance of the lesion observed in persons who had never worked under compressed air or had been exposed to violent changes in atmospheric pressures was the same as that of the lesions in persons who gave a definite history of caisson disease.

An essential clinical point is that when the human body is subjected to sudden decompression, as well as excessive compressed air, bone infarctions may develop. Sudden decompression can be produced when there is loss of pressure in an airplane flying at a high altitude or in an airplane making a very rapid ascent without the necessary equipment for adjusting the pressure.

Other well established causes of localized infarction of bone are sickle-cell anemia [7] and chronic hemolytic anemia due to a combination of sickle-cell anemia and the Cooley trait [14]. These conditions have more often been associated with aseptic necrosis of the epiphyses, and at post mortem examination the infarcts that have been found in numerous tissues other than the bones have been attributed to obstruction of the blood vessels by abnormally formed erythrocytes and the formation of thrombi as the result of stasis and anoxia [18].

After studying cases of multiple bone infarcts for a number of years, and having reviewed several autopsies, Phemister in 1948 reported seven cases of bone infarcts, three of which were associated with caisson disease. No infarcts were found in the spleen or kidney in the four patients on whom autopsies were performed. One of these had caisson disease. Phemister did not establish a definite cause for the vascular occlusion in the four patients with no history of caisson disease. Thrombosis, embolism, and local arterial disease of an obscure

nature were considered, but no evidence of these conditions was found in the post mortem studies. Kahlstrom, in 1942, reported four cases of bone infarcts in patients with a negative history of exposure to increased pressure; three of these patients presented characteristic clinical signs of moderate to severe arteriosclerosis. It is interesting to note that both patients reported in this paper were past middle age and exhibited signs of generalized arteriosclerosis. One of them (Case 2) had had a recent cerebral vascular accident.

We have not found a specific report in the literature of a malignant mesenchymal tumor originating at the site of a bone infarct. Malignant changes associated with benign pathological processes in bone are well recognized, such as tumors developing in association with Paget's disease, malignant changes associated with long-standing chronic osteomyelitis with draining sinuses, and the malignant changes that are seen in a small percentage of cases of polyostotic fibrous dysplasia. Numerous cases of osteogenic sarcoma developing after large doses of roentgen or gamma rays on normal bones have also been reported [5,9]. It is not suggested that radioactive substances could produce the bone infarcts observed in our patients but the findings suggest that some other noxious agent may be responsible for both the infarcts and the malignant tumors.

We have no explanation for the apparent relationship between the bone infarcts and associated fibrosarcomata found in our two patients. A hypothesis to explain the sequence of events could tie in with the disputed theory of Warburg on the origin of cancer cells. It is well established that bone infarcts develop as a result of interruption of blood supply followed by bone necrosis produced by tissue anoxia. Warburg theorized that cancer cells originate from normal body cells in two phases. The first phase is irreversible injury of respiration, which he feels is the common cause into which all other causes of cancer merge. This irreversible injury of respiration is followed by a second phase of cancer formation. This consists of a long struggle for existence by the injured cells to maintain their structure in which a part of the cells perish from a lack of energy, while another part succeeds in replacing the irretrievably lost respiration energy by fermentation energy. Because of the morphological inferiority of fermentation energy, the highly differentiated body cells are converted into undifferentiated cells that grow wildly—the cancer cells. Some association between the events reported in our two cases and this theory may exist.

SUMMARY

Two patients were studied with multiple, idiopathic bone infarcts secondarily complicated by the development of fibrosarcoma at the site of infarction. Similar association of these lesions has not been reported in the literature. A brief review is presented of the pathophysiology of caisson disease and bone infarcts. An analysis of other known causes of bone infarcts failed to provide an explanation for the multiple bone infarcts present in these two patients, and similarly no direct relation was found in these cases to other benign bone lesions complicated by malignant-tumor formation.

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Comparative Vascularization of Autogenous and Homogenous-Bone Transplants*†

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This study was carried out to compare the relative rates and amounts of vascularization of fresh autogenous and homogenous-bone transplants. In a relevant paper, Ham observed in pigs that autogenous-skin transplants are vascularized on the seventh day following transplantation. This was accomplished by union of host capillaries with surviving vessels in the transplant. Homogenous-skin transplants under the same circumstances were not vascularized at ten days. Mitosis has been observed in homogenous-skin transplants several days after transplantation [3]. Skin cells survive transplantation because of an efficient extravascular nutritional mechanism which prevents necrosis prior to vascularization.

TABLE I

NUMBER AND TYPE OF PREPARATION

Day after Transplantation	Autogenous	Homogenous
2	8	7
3	9	9
4	9	8
5	7	8
6	8	7
7	6	7
8	11	9
9	9	8
10	9	8

It appears that the periosteal cells of transplanted bone survive for the same reason. Following autogenous transplantation, the periosteal cells proliferate and aid in the incorporation of the transplant. With homogenous transplants, on the other hand, the initial periosteal proliferations from fresh homogenous-bone transplants do not survive the inflammatory response that is produced by the host. The precise mechanism of this rejection is unknown [2].

Reports on the vascularization of bone vary. Hancox observed vessels with circulating cells in small bone fragments five hours after transplantation to the chorio-allantoic membrane of the chicken. He concluded that the vessels survived transplantation and united with capillaries of the host.

Bertini observed superficial vessels in holes punched in autogenous cortical-bone transplants on the fifth day.

Kiehn and his associates, using the transparent-chamber technique in rats, reported that vascularization of autogenous transplants to the dorsal subcutaneous fascia occurred on the eighth day following transplantation.

Stringa, using a dye injection technique in rabbits, observed vessels which penetrated to a depth of 0.3 centimeter in cortical autogenous transplants at seven days. Homogenous transplants were not penetrated by host vessels for three weeks.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 24, 1959.

† This work was supported by a grant from the Easter Seal Research Foundation.

FIG. 1

Autogenous transplant, six days: Beneath the cellular proliferating periosteum (middle) are numerous immature osteoid bars with many proliferating vessels among them. Some of these vessels are filled with India ink. Mesenchymal cells and capillaries (above) surround the transplant. Few inflammatory cells are to be seen. In the cortex of the transplant (below) most of the lacunae are empty; a few contain osteocytes (× 125).

Kreuz and his associates observed vascularization of both freeze-dried and frozen cortical homogenous-bone transplants in dogs at thirty-five days. No special technique was used to demonstrate the vessels and the vascularization was not of primary interest.

All of these studies refer to vascularization of transplanted cortical bone. No mention is made of the vascularization of periosteal proliferations about the transplant.

The purpose of this investigation was to determine the time intervals following transplantation at which vessels of the host enter the periosteal proliferations derived from autogenous and homogenous transplants and to compare the two vascular responses. The rate of this vascularization and its effect on the survival of the transplant was studied during the first ten post-transplant days.

METHOD

Pairs of 100-gram female Sprague-Dawley rats were used. Autogenous transplants in the form of short segments of the femoral shaft (five to seven millimeters in length) with the periosteum of the transplanted bone intact were obtained from the middle third of the right femur. These grafts were then replaced in their

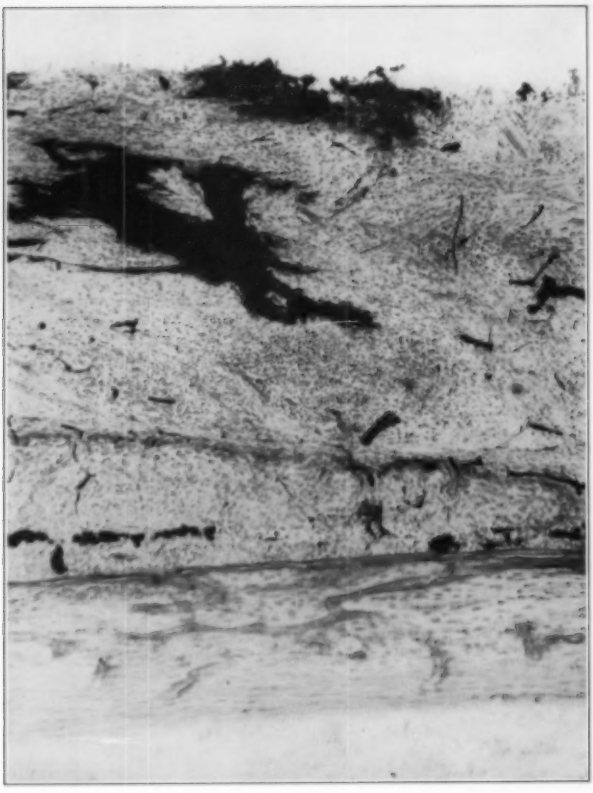

FIG. 2

Homogenous transplant, six days: The surrounding tissues, the periosteal proliferation and associated immature osteoid bars, the vessels, and the cortex of the homogenous transplant show changes similar to those seen with the autogenous graft (Fig. 1). There are perhaps a few more inflammatory cells here than with the autogenous graft (× 125).

original sites and immobilized with an intramedullary Kirschner wire. Homogenous transplants were prepared by exchanging the middle thirds of the left femora between the paired animals by the same technique that was employed for autogenous transplants. At daily intervals of two to ten days after transplantation the abdominal aorta of the host animal was injected with eight to ten cubic centimeters of heparinized India ink. After perfusion, the animals were sacrificed. Sagittal sections of the entire femur were made for histological study. One hundred and forty-seven specimens obtained from forty pairs of animals were studied. Table I demonstrates the number and type of preparation examined.

RESULTS

At two days the periosteal proliferations of the autogenous transplant were four to twelve cells thick and there were large ink-filled vessels within this layer of proliferating cells. Approximately one-half of the lacunae in the cortical bone of the transplant were devoid of osteocytes. The periosteal proliferations and the untraumatized cortex of the host bone contained many ink-filled vessels. A zone of edema, infiltrated with inflammatory cells, surrounded the transplant. Several large vessels were present in this zone. The homogenous preparation at this time was similar in every respect to the autogenous.

Four days after transplantation the periosteal proliferations of the autog-

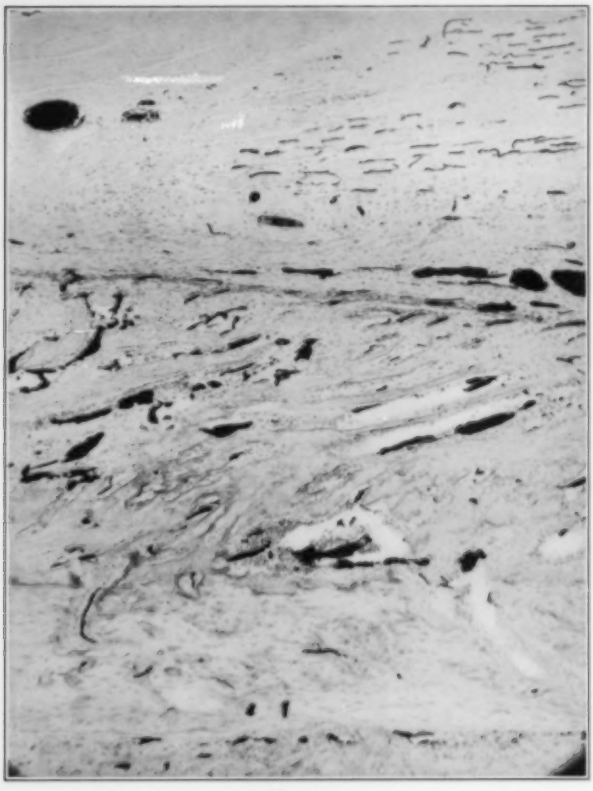

FIG. 3

Autogenous transplant, ten days: By this time the extensive periosteal proliferations (middle) contain large vascular areas, and the trabeculae formed in this proliferating tissue are maturing and blending with the original cortex of the transplant. The cortex of the transplant with its empty lacunae is seen to be deeply penetrated by vessels. No inflammatory reaction is apparent in the surrounding tissues (above) (× 125).

enous graft had increased in thickness to three-fourths the width of the original cortex and there was some early osteoid formation. Several large vessels were present within the zone of proliferating periosteal cells. Only one-fourth of the lacunae in the transplanted bone contained viable osteocytes. There were edema and inflammatory cells about the transplanted cortex. The autogenous and homogenous transplants were still comparable.

At six days immature osteoid bars had appeared in the periosteal proliferations about the transplant. There were numerous vessels in the spaces between the osteoid bars. Some of the lacunae of the transplanted bone still contained osteocytes. Vessels were seen entering the cortex of the transplant. Mesenchymal cells and capillaries were present about the transplant but few inflammatory cells were to be seen (Fig. 1). At six days there was no difference between the autogenous and homogenous specimens (Fig. 2).

Eight days after transplantation the periosteal new bone about the autogenous graft had increased in thickness still more. The osteoid bars were heavier. The vessels between the osteoid bars were larger and more numerous. Osteocytes were visible less frequently in the lacunae of the transplant. The number and the depth of penetration of the vessels in the cortex had not significantly increased. Although the periosteum of the homogenous transplant was well vascularized at this time, inflammatory cells, predominantly lymphocytes, were now seen along the free border of the periosteal proliferations.

FIG. 4

Homogenous transplant, ten days: The homogenous transplant, with its proliferated periosteum and osteoid bars, is now surrounded by a marked inflammatory reaction (above) that is infiltrating the periosteal tissue (middle). No host vessels can be seen entering the periosteal proliferations (no vessels are filled with India ink in this region). There is necrosis of this proliferated tissue and the transplanted cortex (below) (× 125).

Nine days after transplantation the periosteal proliferations of the autogenous transplant were maturing. Vascular lakes were forming between trabeculae and further penetration of vessels into the transplanted cortex had occurred. No inflammatory reaction was visible.

In contrast to this the periosteal proliferations of the homogenous transplant were surrounded by a zone of inflammatory cells at nine days. These cells tended to clump about the vessels, and necrosis of some of the cells within the periosteal proliferations was now apparent. There were also fewer vessels demonstrated within the proliferations.

Ten days after transplantation the periosteal proliferations of the autogenous transplant contained large vascular areas. The trabeculae were maturing. There was further penetration of the cortex by vessels and no inflammatory reaction had occurred (Fig. 3).

About the homogenous transplant, on the other hand, there was a marked inflammatory infiltrate about and within the periosteal proliferations. Vessels from the host could no longer be seen entering the periosteal proliferations and these proliferations were necrotic (Figs. 4 and 5).

CONCLUSION

In rats periosteal proliferations of autogenous and homogenous transplants

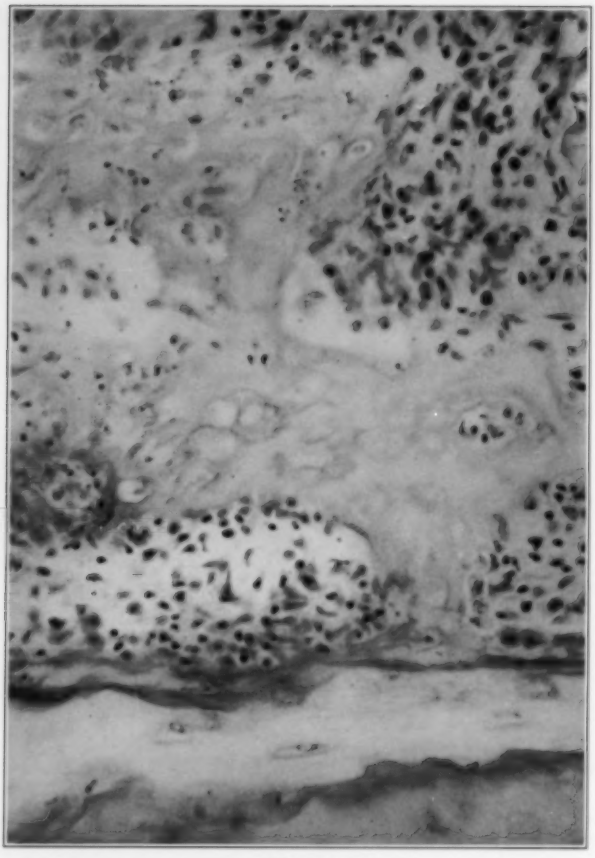

FIG. 5

Homogenous transplant, ten days: A high-power view of the periosteal proliferations shows necrosis of the cells within the new trabeculae. The spaces between these trabeculae contain numerous inflammatory cells. No vessels are to be seen. The lacunae of the transplanted cortex are empty (× 620).

are vascularized within forty-eight hours after transplantation. Until the eighth day after transplantation there is no detectable difference between autogenous and homogenous-bone transplants. In the ensuing seventy-two hours the autogenous transplant continues to proliferate but the homogenous transplant evokes an inflammatory response that obliterates the vascular supply to its periosteal proliferations. The periosteal proliferations from the homogenous transplants undergo necrosis by the tenth day after transplantation.

Determination of the interval following transplantation at which the original vascular ingrowth to homogenous-bone transplants is obliterated may be a method of quantitatively evaluating the intensity of the inflammatory response to various types of transplants.

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Thirteen Cases of Alkaptonuria from One Family Tree with Special Reference to Osteo-Arthrosis Alkaptonurica

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According to Nakamura, sixteen cases of alkaptonuria had been reported in Japan prior to 1949. Six of these were in members of one family tree, the K. K. family, who had lived in a village in Northern Kyushu for a long time.

We, personally, examined the K. K. family more thoroughly and found seven additional cases of alkaptonuria—six in living members of the family, and in one member who had already died evidence that the alkaptonuria had been present. This made a total of thirteen cases of the disease from one and the same family tree. It is interesting to note that there are many consanguineous marriages in this family, as seen in the genealogical table (Chart I). The six living members seen by us had ochronosis together with alkaptonuric osteo-arthritis. Although one of us (N.O.) has made a brief report about these cases in the Japanese literature, the osteo-arthritis was not described. Nor was it described by Nakamura in his report.

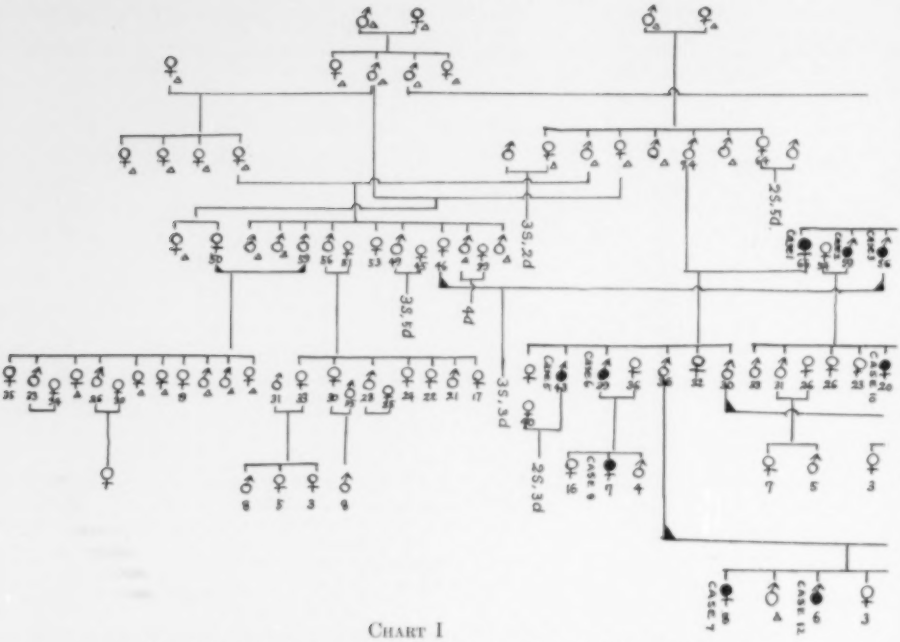


CHART I

Genealogical chart of thirteen alkaptonuric patients in the K. K. family.

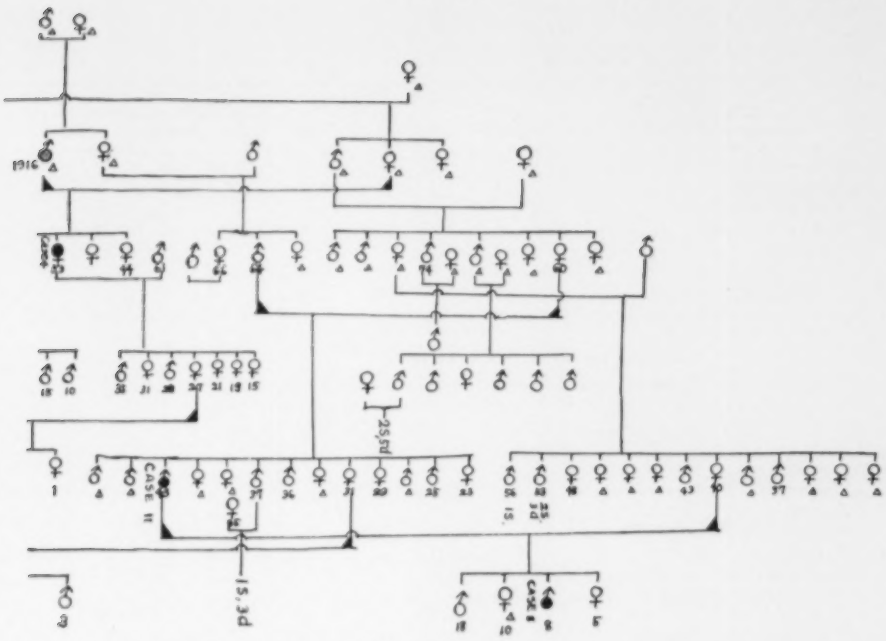
The numbers in the chart indicate age in years. The symbols used indicate, as follows: ♂ = male; ♀ = female; s = son; d = daughter; △ = deceased; and = consanguineous marriage.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Anteroposterior view of the thoracolumbar spine showing osteoporosis, narrowing of the intervertebral spaces, calcification of the intervertebral discs, marginal lipping of the vertebral bodies, and slight scoliosis of the lumbar spine.

Fig. 1-B: Osteoporosis and bone hypertrophy at the margin of the articular surfaces of the shoulder joint, at the greater tuberosity, and at the insertion of the deltoid muscle.



GENETIC STUDY

After examining the census register of the village and having consulted further with many aged men living in the village, we composed the genealogical tree of the K. K. family for five generations (Chart I). Each of the 154 living members of the family was carefully investigated. The urines were tested for homogentisic acid with three reagents: alkaline (with ammonia) silver nitrate, dilute ferric chloride, and sodium hydroxide solution. Twelve persons were found to be alkaptonuric.

Individual detailed inquiry concerning the sixty-nine deceased members

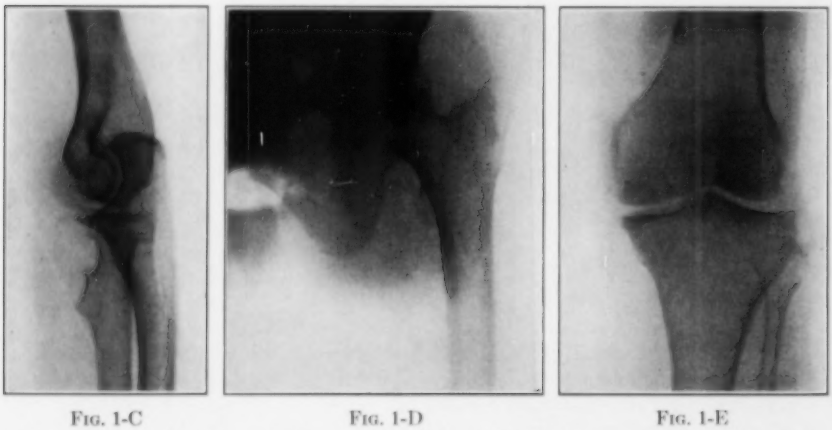


FIG. 1-C FIG. 1-D FIG. 1-E

Fig. 1-C: Slight bone hypertrophy at the insertion of the triceps muscle into the olecranon, moderate hypertrophy at the tuberosity of the radius, and lipping of the coronoid process.

Fig. 1-D: Bone hypertrophy at the greater and lesser trochanters, the tuberosity of the ischium, and the margin of the acetabulum; and subchondral sclerosis at the sacro-iliac joint.

Fig. 1-E: Osteoporosis, narrowing of the joint space of the knee, and bone hypertrophy at the margin of the articular surfaces of the knee joint.

TABLE I

CONSANGUINEOUS MARRIAGE AND THE ALKAPTONURIC PATIENT

Relationship of Couples	No. of Couples	No. of Alkaptonuric Descendants		
		Male	Female	Total
First cousins	2	2	2	4
Second cousins	4	3	1	4
Aunt and nephew	1	0	0	0
Unknown	1	1	0	1
No relation	34	2	2	4
Totals	42	8	5	13

TABLE II

CAUSES OF DEATH IN SIXTY-NINE MEMBERS OF THE K. K. FAMILY

Cause of Death	No. of Deaths
Apoplexia	2
Cancer	1
Pneumonia	1
"Ekiri"	4
Eclampsia	1
Premature birth (died within 1 mo. after birth)	9
Malnutrition (died within 6 mos. after birth)	10
Unknown (11 died before the age of three years)	39
Accident	2
Total	69

of the K. K. family was made of the living relatives with particular reference to their health and the causes of death. One of these sixty-nine individuals was undoubtedly alkaptonuric. He (Case 9) died in 1916, at the age of forty-four. According to his children he had had significant ochronosis of the auricles and sclerae, and had suffered from lumbago and pain in the knee joints for several years. The correlation of consanguineous marriages and alkaptonuria in this family tree is summarized in Table I.

The incidence of consanguineous marriages in Japan is generally high. According to Yanase it is from 5 to 7 per cent in Western Japan and in some villages it may be more than 20 per cent.

The causes of death of the sixty-nine deceased members of the family were surveyed and summarized, as shown in Table II. These deaths did not apparently result from the disease. The high death rate in infancy and early childhood reflects to some extent the unhealthy condition of descendants of consanguineous marriages.

BIOCHEMICAL STUDY

General Analysis of Urine

Twenty-four-hour urine specimens from ten alkaptonuric subjects kept on ordinary diets were analyzed. From a portion of each of these urines the homogentisic acid was extracted with ether at acidic reaction (H_2SO_4) for study. The remaining urine was analyzed for the following constituents: homogentisic acid (Lieb and Lanyar); creatinine (Jaffe); uric acid (Benedict, Franke's direct method); urea (diacetyl monoxime); ammonia (Folin); total nitrogen (Kjeldahl); and Vakat-O (Müller). The results obtained are presented in Table III. For comparison a similar analysis of twenty-four-hour urine specimens from fourteen healthy persons picked at random was performed. Their ages ranged from twenty-

TABLE III

QUANTITATIVE ANALYSIS OF TWENTY-FOUR-HOUR URINE SPECIMENS FROM TEN ALKAPTONURIC PATIENTS

Case No. and Sex Age (*Years*)	1, F 66	2, M 59	3, M 56	4, F 53	5, M 43	6, M 39	7, F 8	8, M 8	9, F 7	12, M 6
24-hour urine (*milliliters*)	925	2,430	2,030	2,140	1,230	1,510	380	1,240	765	375
Specific gravity	1.020	1.015	1.017	1.015	1.027	1.022	1.035	1.015	1.025	1.025
Homogentisic acid (*grams*)	1.647	2.736	2.992	2.922	6.061	4.198	1.235	3.036	0.161	0.095
Creatinine (*grams*)	0.883	1.750	1.786	1.370	2.657	2.089	0.556	0.868	0.268	0.131
Uric acid (*grams*)	1.517	3.208	3.410	2.868	3.149	3.201	0.927	1.810	0.184	0.090
Urea (*grams*)	4.166	9.666	14.616	11.770	19.680	12.321	2.660	4.235	6.554	3.013
Ammonia (*grams*)	0.962	0.774	0.982	0.667	0.857	0.948	0.432	0.660	0.246	0.104
Total nitrogen (*grams*)	3.564	6.890	9.298	7.535	11.946	8.418	2.149	3.484	3.478	1.629
Vakat-O (*grams*)	10.822	18.197	17.304	19.538	23.631	23.864	6.993	11.875	10.077	4.173
$\frac{\text{Vakat-O}}{\text{Total nitrogen}}$ (*per cent*)	303.64	264.10	186.10	259.29	197.81	283.48	325.40	340.84	289.73	256.16
$\frac{\text{Creatinine nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	9.20	9.43	7.13	6.75	8.26	9.22	9.61	9.25	2.86	2.98
$\frac{\text{Uric acid nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	14.19	15.52	12.68	12.69	8.78	12.67	14.38	17.32	1.76	1.84
$\frac{\text{Urea nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	54.52	65.44	73.33	72.87	76.85	68.27	57.74	56.70	87.90	86.28
$\frac{\text{Ammonia nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	22.19	9.24	6.91	7.28	5.90	9.26	16.53	15.58	5.81	5.25
Total (*per cent*)	100.10	99.63	99.59	99.58	99.79	99.42	98.26	98.85	98.33	96.35

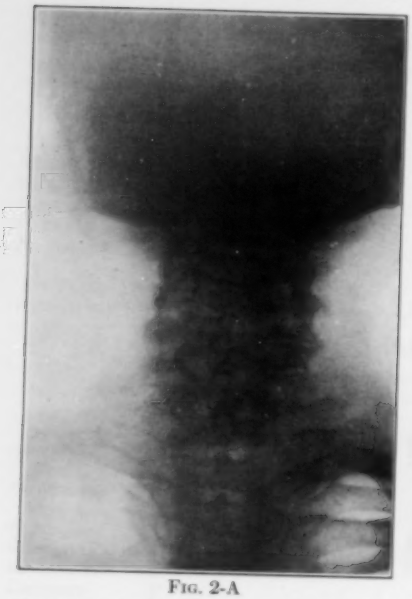


FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Bone hypertrophy at the lateral joints of the cervical spine.
Fig. 2-B: Osteoporosis, characteristic wafer-like appearance of the intervertebral spaces; marginal lipping and bridging of the vertebral bodies; bone hypertrophy of the spinous processes; and slight scoliosis.

FIG. 2-C

FIG. 2-D

Fig. 2-C: Slight osteoporosis; bone hypertrophy at the glenoid of the scapula and at the insertion of the deltoid muscle into the humerus; and so-called "Kienböcksche rundherde".
Fig. 2-D: Bone hypertrophy at the insertion of the triceps into the olecranon and at the tuberosity of the radius; and lipping of the coronoid process.

eight to sixty-one years. They all lived in other villages and towns and were not related to the K. K. family (Table IV).

Homogentisic Acid

Case 2 was admitted to our hospital for the repair of an acute rupture of his Achilles tendon. While in the hospital he was maintained on an almost constant diet (rice, fish, and vegetables), and the excretion of homogentisic acid in the urine per twenty-four hours was determined in two ways: on the diet alone, and then while taking, in addition, first DL-p-methoxyphenylalanine (PMPA) and then L-dihydroxyphenylalanine (DOPA), each for a three-day period. The results

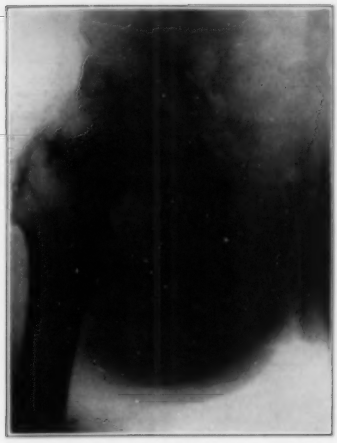


FIG. 2-E

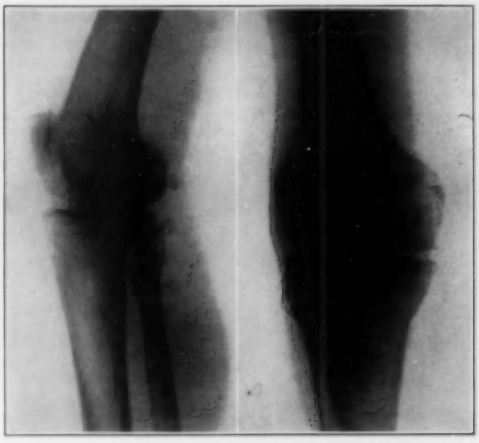


FIG. 2-F

Fig. 2-E: Narrowing of the joint space of the hip; bone hypertrophy at the margin of the acetabulum and of the articular surface of the femoral head and at the greater and lesser trochanters; cystic change in the greater trochanter; and subchondral-bone sclerosis at the sacro-iliac joint and at the articulation between the pubic bones.

Fig. 2-F: Narrowing of the joint space of the knee; bone hypertrophy at the margin of the articular surface of the tibia and at the insertion of the quadriceps muscle into the patella; and free bone at the proximal end of the fibula.

FIG. 2-G

Bone hypertrophy at the insertion of the Achilles tendon into the calcaneus and at the origin of the short muscles of the foot.

of these feeding experiments are recorded in Table V. No increase in the excretion of homogentisic acid resulted from the ingestion of either of these substances.

Uric Acid

The uric acid excretion in twenty-four hours was determined by the optical-density method at 288 micra and pH 5. The urines of four healthy persons, who were members of the immediate families of the alkaptonurics and living in the same households, were used as controls. As shown in Table VI, all five of the adults and two of the four children with alkaptonuria excreted more uric acid per twenty-four hours than did the four normal controls.

TABLE IV

QUANTITATIVE ANALYSIS OF TWENTY-FOUR-HOUR URINE SPECIMENS OF FOURTEEN HEALTHY PERSONS

Analysis	Mean	Maximum	Minimum
24-hour urine (*milliliters*)	1,322	2,320	800
Specific gravity	1.020	1.030	1.008
Creatinine (*grams*)	1.559	2.162	1.263
Uric acid (*grams*)	0.691	1.183	0.450
Urea (*grams*)	18.889	26.520	11.180
Ammonia (*grams*)	0.700	1.215	0.392
Total nitrogen (*grams*)	10.300	15.086	6.777
Vakat-O (*grams*)	15.977	23.542	10.164
$\frac{\text{Vakat-O}}{\text{Total nitrogen}}$ (*per cent*)	162.49	260.49	93.82
$\frac{\text{Creatinine nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	5.78	9.70	4.61
$\frac{\text{Uric acid nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	2.22	2.76	1.62
$\frac{\text{Urea nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	85.47	89.15	76.96
$\frac{\text{Ammonia nitrogen}}{\text{Total nitrogen}}$ (*per cent*)	5.70	8.35	3.47
Totals (*per cent*)	99.17	109.96	86.66

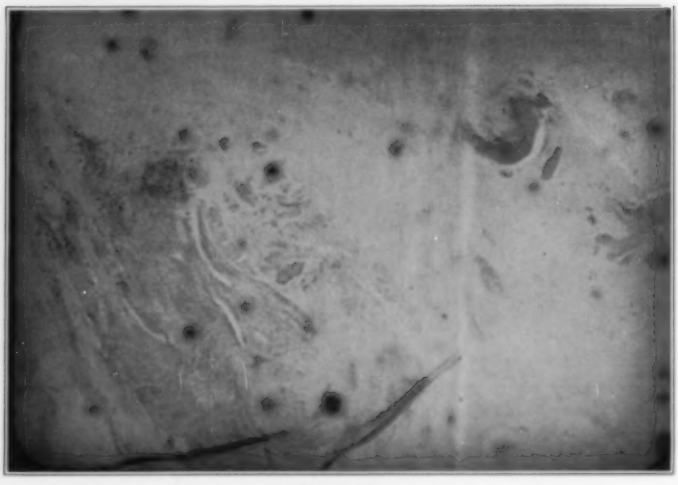


FIG. 2-H

Photomicrograph of the ruptured Achilles tendon showing granular and homogeneous pigment precipitations in and around the degenerated tendon fibers.

From these studies it seems evident that homogentisic acid in alkaptonuria is not formed from either DL-p-methoxyphenylalanine or L-dihydroxyphenylalanine. These findings indicate that a methyl group attached to the hydroxyl group on the phenol ring prevents further oxidation of the phenol ring of DL-p-methoxyphenylalanine in the alkaptonuric and that rearrangement of the catechol molecule in L-dihydroxyphenylalanine to hydroquinone also does not occur in the alkaptonuric.

TABLE V

HOMOGENTISIC ACID EXCRETED BY PATIENT IN CASE 2

Date (*Month and Day*)	Urine (*Milliliters*)	Homogentisic Acid (*Grams*)	Drug and Dosage (*Grams*)
3/31	1,500	4.001	
4/1	1,480	5.523	
4/2	1,880	4.786	
4/3	1,240	4.437	
4/7	1,400	3.435	3, DL-p-methoxyphenylalanine
4/8	1,300	4.676	3, DL-p-methoxyphenylalanine
4/9	1,680	5.043	3, DL-p-methoxyphenylalanine
4/12	1,170	3.057	1.5, L-dihydroxyphenylalanine
4/13	1,520	3.921	1.5, L-dihydroxyphenylalanine
4/13	1,780	4.150	1.5, L-dihydroxyphenylalanine

TABLE VI

URIC ACID CONTENT IN ALKAPTONURIA

Case No.	Sex	Age (*Years*)	Urine (*Milliliters per Day*)	pH	Dilution	Uric Acid: Milligrams per Liter	Uric Acid: Grams per Day
1	F	66	865	5.0	×100	13.82	1.195
2	M	59	1,810	5.0	×100	9.52	1.721
3	M	57	2,100	5.0	× 50	9.92	1.042
4	F	53	1,630	5.0	×100	8.52	1.389
6	M	39	1,590	5.0	×100	7.53	1.197
Mean: adult patients			1,599	5.0			1.308
7	F	8	1,290	5.0	× 50	17.85	1.079
8	M	8	1,460	5.0	×100	5.69	0.837
9	F	7	575	5.0	× 50	9.16	0.236
12	M	6	1,280	5.0	× 50	7.53	0.482
Mean: child patients			1.151	5.0			0.665
Son of Case 1		38	2,430	5.0	× 50	6.08	0.738
Son of Case 3		18	1,660	5.0	× 50	5.98	0.482
Daughter of Case 4		18	1,420	5.0	× 50	7.86	0.558
Mother of Case 8		42	1,440	5.0	×100	5.44	0.780
Mean: healthy persons			1,737	5.0			0.641

At the same time it would appear that in alkaptonuria the metabolism of the aromatic amino acids, uric acid, and the purine bases is impaired. The urines examined from members of the K. K. family with alkaptonuria contained more uric acid than the urines of the normal members of the same family. It seems unlikely that just those members of the family with alkaptonuria would have the uric acid diathesis. Furthermore, the urine from a person with alkaptonuria from another region, which was kindly provided by Professor K. Ichihara of the Osaka University Medical School, also showed a high uric acid excretion (1.42 grams per day).

SYMPTOMS AND CASE REPORT

The symptoms of twelve patients are summarized in Table VII.

Case 2. K. K., a male farmer, fifty-nine years old, had had lumbago since the age of thirty and radiating pain into both buttocks and both lower extremities since the age of forty. When he was fifty years old, he first noticed that his urine turned black when it was left standing. Five years later he began having pain in his Achilles tendons. He had been healthy and never had had any disease worth mentioning. His wife was healthy and bore him four sons and three daughters. One of the daughters had alkaptonuria (Case 10).

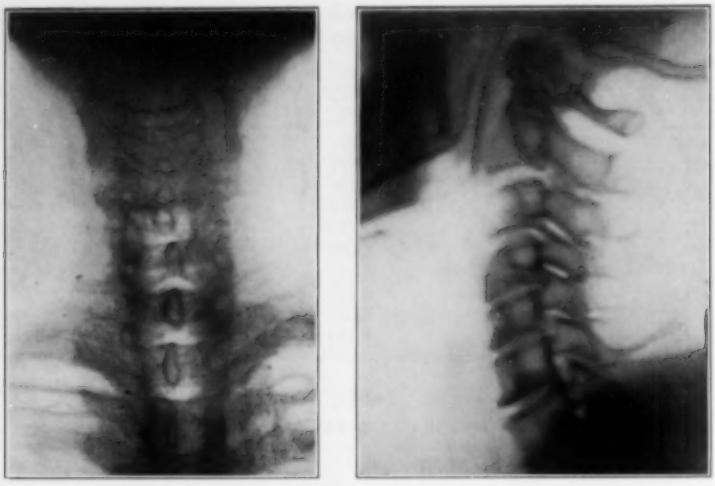


FIG. 3-A

Case 3. Slight marginal lipping of the lower two cervical vertebral bodies.

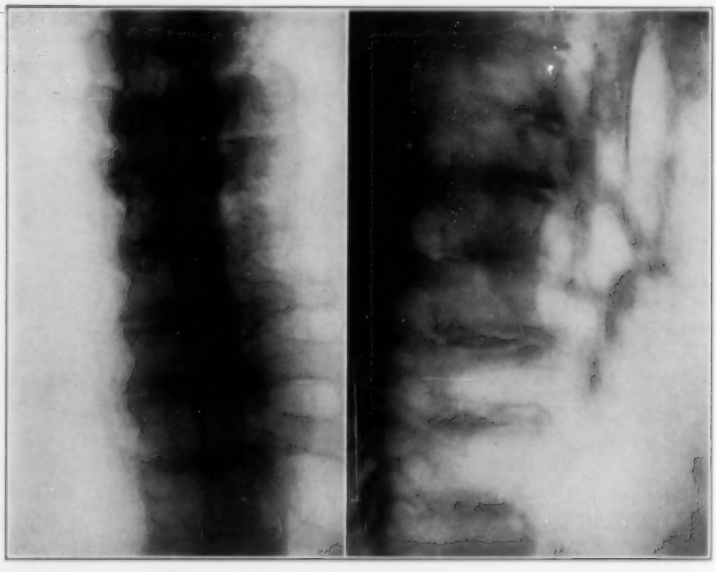


FIG. 3-B

Characteristic wafer-like change of the intervertebral discs, marked narrowing of the intervertebral spaces, marginal lipping of the vertebral bodies, and hypertrophy of the spinous processes.

The patient was short, well built, and well nourished. His neck was shortened and its motion markedly limited. He had round kyphosis in the thoracolumbar spine and a slight scoliosis convex to the left in the lower portion of the spine. The thoracolumbar spine was so completely rigid that the patient could not lie on his back. Each of the spinous processes in the thoracolumbar region was hypertrophied and the intervals between them could not be identified. The tissues on each side of the spinous processes were tough and tender on palpation. Restricted motion was observed in both shoulders and hips, and both knee joints were widened and deformed.

Roentgenographic examination revealed changes in the cervical spine that included osteoporosis of the vertebral bodies, marginal lipping on the edges of the vertebral bodies, and marked thinning of the intervertebral discs (Fig. 2-A).

In the cervical, thoracic, and lumbar spine the disc spaces were narrow with wafer-like hori-

FIG. 3-C

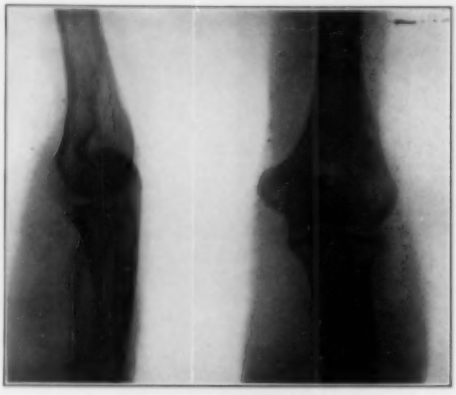


FIG. 3-D

Fig. 3-C: Bone hypertrophy at the margin of the glenoid of the scapula and at the insertion of the deltoid muscle into the humerus.
Fig. 3-D: No remarkable change.

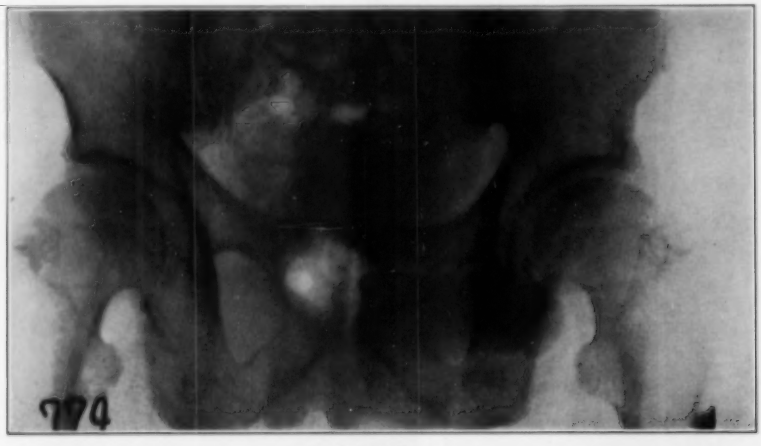


FIG. 3-E

Slight hypertrophy of bone at the margin of the acetabulum.

zontal bands of calcification in each space. The contours of the laminae and lateral joints were indistinct. These changes were most marked in the lumbar region (Fig. 2-B).

In the shoulder joint the roentgenograms showed osteoporosis in the humeral head, glenoid cavity, and acromion; hypertrophic changes on the borders of the articular surfaces and at the insertion of the deltoid muscle on the humerus; and the so-called "Kienböcksche rundherde" and lacunar absorption of bone in the upper end of the humerus (Fig. 2-C). In the elbow joints hypertrophic changes were seen on the olecranon, coronoid process, and radial tuberosity (Fig. 2-D).

The roentgenograms of the hips and pelvis showed subchondral sclerosis of bone in the sacroiliac joints; narrowing of the joint spaces in both hips; bone spurs on the margins of the acetabula, along the border of the articular surface of the femoral head on the greater and lesser trochanters; and lacunar absorption of bone in the greater trochanter. There was generalized osteoporosis of the pelvis, as well as osteosclerosis in the tuber ischii, cystic changes in the pubis and ischium, and aberrant new-bone formation in the soft tissues near the tuber ischii (Fig. 2-E).

In the knee joints the roentgenograms showed marked narrowing of the joint spaces, bone spurs on the borders of the articular surfaces and at the insertion of the quadriceps muscle into the patella, osteoporosis of the bone in the region of the medial and lateral epicondyles of the femur, and some aberrant new-bone formation posterior to both knee joints (Fig. 2-F).

In the calcaneus bone spurs were present at the insertion of the Achilles tendon and the origin of the short flexor muscle of the toes (Fig. 2-G).

On the way to the hospital the patient ruptured his left Achilles tendon when he got off the train. Suture of the ruptured tendon was performed immediately after admission to the hospital.

FIG. 3-F

Narrowing of the joint space of the knee and slight bone hypertrophy at the margin of the articular surface of the tibia.

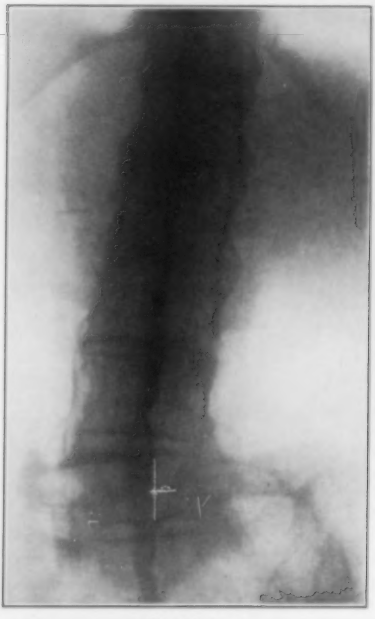


FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 4. Scoliosis, osteoporosis, narrowing of the intervertebral spaces, wafer-like appearance of the discs, marginal lipping and bridging of the vertebral bodies, and hypertrophy of the spinous processes.

Fig. 4-B: Marginal bone hypertrophy at the acetabulum and unevenness and cystic bone changes in the tuber ischii.

At operation, the tendon was found to be completely ruptured at its insertion into the calcaneus. The proximal end of the ruptured tendon was hard and thickened. For a distance of two centimeters proximal to the rupture the tendon was dark brown, resembling incompletely burned wood. The portion of the tendon left on the calcaneus was small and was also dark brown. The tuber calcanei was uneven with the bone spurs revealed in the roentgenogram. This bone was also brown, but to a slight degree. In the histological sections of the Achilles tendon we observed degenerated and ne-

TABLE VII

Findings in Twelve Patients with Alkaptonuria

Case No. and Sex	1, F	2,M	3, M	4, F	5, M	6, M	7, F	8, M	9, F	10, F	11, M	12, M
Age (*years*)	66	59	56	53	43	39	8	8	7	20	43	6
Height (*inches*)	43	59	56	55	60	60	51	51	49	58	67	44
Weight (*pounds*)	75	111	115	92	108	111	62	84	60	93	142	56
Chest measurement (*inches*)	30	34	32	32	33	33	27	25	24	28	36	22
Past illness			Pulmonary infiltration		Malaria	Malaria; pleurisy						
Chief complaints	Urine coloring; lumbago, since 30 yrs. of age; pain radiating to lower extremities, since 56 yrs.; skin coloring, since 60 yrs.	Urine coloring; lumbago, since 30 yrs. of age; pain radiating to lower extremities and pain at knee joint, since 40 yrs.; skin coloring since 50 yrs.	Urine coloring; lumbago, since 36 yrs. of age; pain radiating to lower extremities, since 50 yrs.	Urine coloring; lumbago, since 43 yrs. of age; pain radiating to lower extremities, since 53 yrs.	Urine coloring; lumbago, since 30 yrs. of age; pain at knee joints, since 42 yrs.	Urine coloring; lumbago, since 37 yrs. of age	Urine coloring	Urine coloring; lumbago, since 7 yrs. of age	Urine coloring	Urine coloring	Urine coloring; lumbago, since 35 yrs. of age	Urine coloring
Ochronosis												
Auricle	+++; thick, deformed	++	++	++	+; thick, deformed	+	+	+			+	
Sclera	+++	++	++	+	+							
Finger nail	+++	++	+	++								
Nose	++	++	+									
Cheek	++	+	+									
Back of head	+	+										
Cerumen	+	+	+	+	+							
Kyphosis	++	+	+									
Bone and joint injury	+++	+++	++	+	+							
Vision	Weak	Weak	Weak	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Dysacousia	+	+	+									
Pulse (*rate per minute*)	80	65	78	68	67	72	100	92	76	73	60	88
Blood pressure (systolic/diastolic)	145/78	165/90	125/78	182/78	100/60	151/86	102/76	92/51	98/62	115/85	115/80	83/45
Heart findings	Hypertrophy, 5 cm. to right; impure sound	Hypertrophy, 3 cm. to right; noise at apex	Hypertrophy, 1.5 cm. to right; impure sound	Normal	Noise at apex	Noise at apex	Normal	Normal	Normal	Normal	Normal	Normal
Tendon reflexes	Decreased	Decreased	Increased	Decreased	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal
Nervous system	Finger tremor, +											
Test for homogentisic acid with:												
Sodium hydroxide	+++	+++	+++	+++	+++	+++	+++	+++	+	+	+	+
Silver nitrate-ammonium hydroxide	+++	+++	+++	+++	+++	+++	+++	+++	+	+	+	+
Ferric chloride	+++	+++	++	++	++	++	++	++	+	+	+	+

crotic tendon fibers and granular and homogeneous pigment precipitations in and around the tendon fibers (Fig. 2-H).

SUMMARY AND CONCLUSION

This article concerns the study of a family in which cases of ochronosis had been reported previously. In the present study thirteen members of the family were found to have alkaptonuria and six of these had bone and joint changes typical of ochronosis. The ages of the thirteen alkaptonurics studied here ranged from six to sixty-six years. One member, who had died at the age of forty-four, was not included in the study. The youngest patient showing changes in the bones and joints due to ochronosis was forty-three. The genealogy of this family showed a high incidence of consanguineous marriage.

In the twelve patients with alkaptonuria ochronosis was first observed in the auricles and then in the sclerae, finger nails, nose, and cheeks. Joint symptoms similar to osteo-arthritis appeared after pigmentation had developed, first as lumbago alone and then with the subsequent development of radiating pain in the lower extremities and pain in the joints, with limitation of motion.

Skeletal roentgenograms showed degenerative changes and the formation of spurs of the appendicular joints in five of the twelve patients studied. Joint changes first made their appearance in the lumbar spine, followed by changes in the thoracic and cervical regions. Changes in the other joints appeared subsequently.

In one patient (Case 2) histological examination of the Achilles tendon was possible when a ruptured tendon was repaired. The sections showed degeneration and necrosis of the tendon fibers and diffuse granular deposits of pigment, both within the cells of the tendon and within the extracellular spaces. While this patient was hospitalized he was maintained on a constant diet to which was added first DL-p-methoxyphenylalanine and then L-dihydroxyphenylalanine. No increase in the excretion of homogentisic acid in the urine resulted, and it was concluded that neither of these substances is a precursor of homogentisic acid.

An additional finding in this family was that among the members studied, those with alkaptonuria excreted more uric acid than the normal members of the family. It is suggested that the metabolism of uric acid and of the purine bases is disturbed in the alkaptonuric.

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Bone Metabolism

IV. The Effect of Radioactive Strontium (Sr^{90}) on the Mobilization of Stable Strontium from the Skeleton of the Rat*

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In a previous study [24] the toxic effects and histological changes produced by Sr^{90} and the metabolism of Sr^{90} during the first three days following an $LD_{50}/50$ days dose of the isotope in rats (a dose which resulted in the death of approximately 50 per cent of the animals during the fifty-day experimental period) were described, and it was shown that the general pattern of metabolism at this dose level was the same as that for trace levels of Sr^{90}. In these same animals extensive histological changes in the skeleton, similar to those noted previously by other investigators [2,8,16], were observed two weeks after injection of the isotope. It was suggested that these changes might be accompanied by alterations in bone-salt metabolism. The possibility that radiation damage may delay mobilization of inorganic salts from the skeleton had been advanced previously [1,20,21]. In view of the increasing use of radioactive isotopes in the study of bone metabolism, it appeared that further investigation into this problem would be pertinent.

Another problem, one of clinical importance, relates to mobilization of bone-seeking radioactive emitters from the skeleton. Since it has been shown that mobilization of stable strontium [25] and trace levels of radioactive strontium [12,13] can be enhanced by maintaining rats on diets low in phosphorus, the question arises whether these diets would also be effective with high levels of radioactive strontium.

The purpose of the following experiment was to study: (1) the metabolism of Sr^{90} for fifty to sixty days after a single sublethal intraperitoneal injection of the isotope in young growing rats; (2) the effect of this dose of Sr^{90} on the composition, growth, and metabolism of bone; and (3) the effect of phosphorus-deficient diets on the mobilization of strontium from the skeleton in the presence of radiation damage.

MATERIALS AND METHODS

Approximately 300 male Long-Evans rats, weaned at twenty-one days of age, were placed on a standard laboratory diet and given daily intraperitoneal injections of stable strontium chloride in a solution containing fifty milligrams Sr^{++} per milliliter. The dose, 0.2 milligram Sr^{++} per gram of body weight, was adjusted every three to four days according to changes in body weight associated with growth. After twenty to twenty-one days, the injections of stable strontium were discontinued, and the animals were divided into three major groups, as shown in Table I.

The standard diet used in this experiment was the McCollum Diet I, which contains the optimum amounts of calcium and phosphorus. The subminimal phosphorus diet contained 0.21 per cent phosphorus, approximately one-half the amount necessary for normal growth; the low phosphorus diet, 0.017 per cent phosphorus. The phosphorus level in the latter diet was increased to 0.05 per cent with sodium biphosphate (NaH_2PO_4) after two weeks because of the

* This paper is based on work performed under the United States Atomic Energy Commission Contract #AT(11-1)-507.

cachectic condition of the rats maintained on this diet. A detailed analysis of the diets is included in a previous publication [25].

The rats injected with Sr^{90} were given a single intraperitoneal injection at the onset of the experimental period. Since it was anticipated that Sr^{90} injections at the levels used in this experiment would result in loss of weight, whenever a choice existed, the heavier rats were included in the subgroups injected with Sr^{90}. The dose of Sr^{90}, 2.7 to 3.2 microcuries per gram of body weight, had previously been shown to induce histological changes in the skeleton without killing more than half the rats during a subsequent experimental period of fifty-five to sixty-four days [24]. Of the 173 rats injected with Sr^{90}, 100 died or were sacrificed because of their cachectic condition between the fourteenth and twentieth day after injection. These were eliminated so that the final study was based on a total of 200 rats—seventy-three injected with Sr^{90} and 127 that did not receive Sr^{90}.

Serial isotope determinations were made on the excreta of half of the rats injected with Sr^{90} and the cumulative excretion of the isotope was determined on the remainder to follow the rate of elimination of the isotope.

TABLE I

SUMMARY OF ANIMAL GROUPS

Group	Diet	No. of Rats
A	Standard	84
	Standard, Sr^{90}-injected	32
B	Subminimal Phosphorus	15
	Subminimal Phosphorus, Sr^{90}-injected	17
C	Low Phosphorus	28
	Low Phosphorus, Sr^{90}-injected	24
	Total	200 *

* 100 rats injected with Sr^{90} were eliminated from the experiment, as explained in the text.

At autopsy (fifteen minutes, and one, seven, twelve, fourteen, thirty, thirty-two, forty, fifty-four, fifty-five, and sixty-four days after injection of Sr^{90}) one tibia was removed for histological study and one femur for chemical analysis. Tissues for histological study were fixed, decalcified, embedded, sectioned, and stained by the same technique as in a previous study [24]. Chemical analysis of the femur included determination of the wet weight, the dry weight after twenty-four hours in a drying oven at 95 degrees centigrade, and the ash weight after eighteen hours in a muffle furnace at 600 degrees centigrade. The difference between wet and dry weights was taken as the water content; the difference between dry and ash weights as the organic content (citrate and carbon dioxide are probably affected in the ashing process, but the error introduced is a constant one and should not appreciably influence the conclusions). Quantitative determinations of stable strontium were carried out with a Weichelsbaum-Varney flame photometer by the method previously described [25]. Femora from rats that received Sr^{90} were analyzed for both radioactive and stable strontium.

Radioactivity determinations were made on the femur, carcass, and blood, as well as on the excreta from the animals injected with Sr^{90}. Determinations were carried out using a lead-shielded Geiger-Müller tube with a mica end-window (1.5 mg/cm^2) and a decade scaler. Since Sr^{90} (half-life of twenty-five years) decays to Y^{90} (sixty-five-hour half-life), all samples were held at least fifteen days (six half-lives of Y^{90}) to attain equilibrium prior to counting. An aliquot of each sample was mounted on a two by three-inch glass microscope slide that had been treated with desicote. The micropipette was washed twice with 10 per cent nitric acid and the washings added to the slide. The mount was

then slowly dried under an infrared lamp, care being taken to obtain uniform circular deposits. After drying, the slides were covered with cellophane tape and counted. Determinations made on standard mounts showed that the tape had no significant effect on the counting rate of Sr^{90}–Y^{90} at a distance of 3 centimeters from the Geiger tube window. Counting rates were corrected for source size and back scatter, and at least 5,000 counts were totaled for each mount to minimize the statistical error in counting.

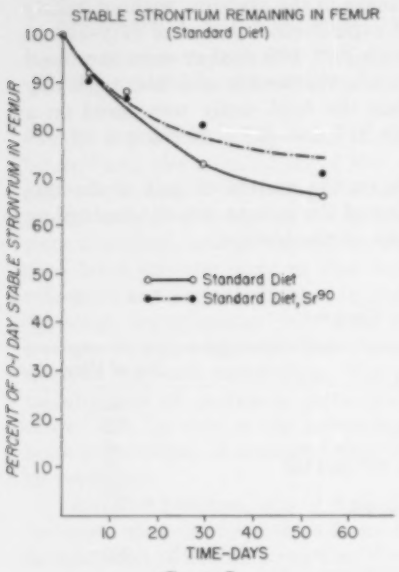

CHART I

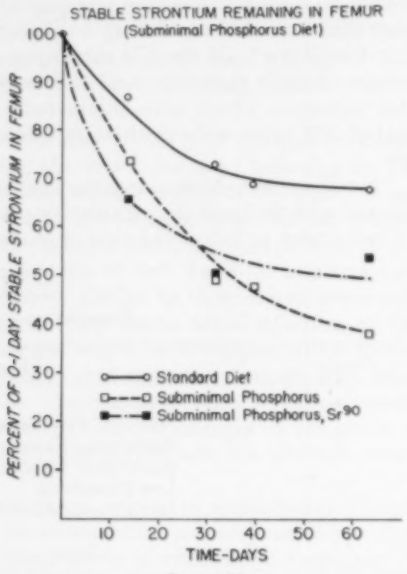

CHART II

RESULTS

Metabolism and Distribution of Strontium in Rats on Standard Diet

Stable strontium (Table II-A): The daily injections of stable strontium during the preliminary period of twenty to twenty-one days, while the rats were maintained on the standard diet, had no appreciable effect on body weight or on the histological appearance of the skeleton. At the end of this period, approximately 1.5 per cent of the total injected dose was found in the femur. After fifty-five days on the standard diet about 1 per cent of the total dose remained, 0.5 per cent having been mobilized during the intervening period. Of the total stable strontium mobilized, 0.02 per cent per day of the original dose was removed from the femur during the first seven days (Chart I), approximately 0.015 per cent per day from the first to fourth weeks, and approximately 0.003 per cent per day between the fourth and ninth weeks.

Radioactive strontium: The blood level at twenty-four hours (Blood Levels, Table III) was 0.125 per cent of the injected dose, at seven days 0.024 per cent, at thirty days 0.007 per cent, and at fifty-five days 0.007 per cent. During the first twenty-four hours after injection approximately 18 per cent of the dose of Sr^{90} was excreted (Excretion, Table III and Chart IV) in the urine and feces (compared with 15 per cent in an earlier study [24]), but individual rats varied considerably in the amount of isotope excreted during this first day. During the next fourteen days approximately 1 per cent per day was excreted, whereas between the fourteenth and thirtieth days the amount excreted was approximately 0.5 per cent per day, and between the thirtieth and fiftieth days the amount excreted was between 0.15 to 0.20 per cent per day. The total excretion of Sr^{90} on the standard diet over the fifty-five-day period was slightly more than 50 per

TABLE II-A

SUMMARY OF RESULTS

Effects of a Single Intraperitoneal Injection of Sr^{90} on Body Weights and Femoral Analyses of Rats on a Standard Diet

Test Period	No. of Rats	Body-Weight Data			Analyses of Femora					
		Initial	Final	Gain	Wet Weight*	Water	Organic	Ash	Stable Sr in Femur	
(*Days*)		(*Grams*)	(*Grams*)	(*Grams*)	(*Grams*)	(*Per Cent*)	(*Per Cent*)	(*Per Cent*)	(*Per Cent of Injected Dose*) *	(*P Values*) **
					Control Rats					
0	10	132	132	0	0.4189 ± 0.0323	52	25	23	1.44 ± 0.10	
1	6	123	123	0	0.4395 ± 0.0542	57	22	21	1.57 ± 0.14	
7	12	126	159	33	0.5330 ± 0.0164	50	24	26	1.32 ± 0.11	
12	6	122	161	39	0.5479 ± 0.0677	46	25	29	1.23 ± 0.07	
14	13	133	195	62	0.5628 ± 0.0292	48	24	28	1.28 ± 0.08	
30	11	124	257	133	0.7249 ± 0.0508	43	25	32	1.08 ± 0.09	
32	2	137	260	123	0.7040 ± 0.0070	44	25	31	1.09 ± 0.10	
40	3	113	261	148	0.6539 ± 0.0679	38	25	37	1.03 ± 0.07	
54	6	139	345	206	0.9345 ± 0.0417	38	25	37	0.93 ± 0.10	
55	11	116	289	173	0.8619 ± 0.0410	39	25	36	1.06 ± 0.12	
64	4	135	280	145	0.7489 ± 0.0989	38	25	37	1.01 ± 0.10	
					*Sr^{90}-Injected Rats****, ****					
1	5	130	130	0	0.4892 ± 0.0359	57	23	20	1.73 ± 0.11	>0.05
7	6	128	111	−17	0.4296 ± 0.0369	46	26	28	1.56 ± 0.12	<0.01
14	6	137	125	−12	0.5341 ± 0.0429	43	30	27	1.50 ± 0.12	<0.01
30	6	129	140	11	0.5463 ± 0.0676	36	34	30	1.40 ± 0.13	<0.01
55	9	131	189	58	0.6410 ± 0.0464	36	31	33	1.22 ± 0.14	>0.05

* Figures are mean values and standard deviations.

** See Footnote a. These probability values (obtained from Fisher's "t" distribution) indicate the significance of differences between Sr^{90}-injected and non-injected (control) rats for the corresponding test periods.

*** Sr^{90} dose was 2.7 microcuries per gram of body weight.

**** The data from 34 rats were not available owing to death or sacrifice of the animals.

TABLE II-B

SUMMARY OF RESULTS

Effects of a Single Intraperitoneal Injection of Sr^{90} on Body Weights and Femoral Analyses of Rats * on a Subminimal Phosphorus Diet

Test Period	No. of Rats	Body-Weight Data			Analyses of Femora					
		Initial	Final	Gain	Wet Weight **	Water	Organic	Ash	Stable Sr in Femur	
(*Days*)		(*Grams*)	(*Grams*)	(*Grams*)	(*Grams*)	(*Per Cent*)	(*Per Cent*)	(*Per Cent*)	(*Per Cent of Injected Dose*) **	(*P Values*) ***
					Rats on Subminimal Phosphorus Diet ****					
14	3	133	156	23	0.5555 ± 0.0162	52	25	23	1.10 ± 0.08	<0.05
32	3	153	176	23	0.6961 ± 0.0595	47	26	27	0.73 ± 0.08	>0.05
40	3	128	185	57	0.6241 ± 0.0681	42	27	31	0.71 ± 0.02	<0.01
64	6	128	240	112	0.7234 ± 0.0178	41	26	33	0.57 ± 0.06	<0.01
					Rats on Subminimal Phosphorus Diet ****, Sr^{90}-Injected *****					
1	4	155	155	0	0.5570 ± 0.0408	57	23	20	1.74 ± 0.05	>0.05
14	4	152	116	−36	0.5111 ± 0.0411	52	28	20	1.14 ± 0.03	<0.05
32	3	147	168	21	0.5821 ± 0.0721	47	29	24	0.87 ± 0.10	>0.05
64	6	149	175	26	0.7017 ± 0.0504	45	28	27	0.93 ± 0.10	>0.05

* The data from 53 rats were not available owing to death or sacrifice of the animals.

** Figures are mean values and standard deviations.

*** See Footnote a and Table II-A. The P values for the difference between the Sr^{90}-injected and non-injected rats on the subminimal phosphorus diet are >0.05 at fourteen days, >0.05 at thirty-two days, and <0.01 at sixty-four days.

**** This diet contained 0.21 per cent phosphorus.

***** Sr^{90} dose was 2.7 microcuries per gram of body weight.

TABLE II-C

SUMMARY OF RESULTS

Effects on a Single Intraperitoneal Injection of Sr^{90} on Body Weights and Femoral Analyses of Rats * on a Low Phosphorus Diet

Test Period	No. of Rats	Body-Weight Data			Analyses of Femora					
		Initial	Final	Gain	Wet Weight **	Water	Organic	Ash	Stable Sr in Femur	
(*Days*)		(*Grams*)	(*Grams*)	(*Grams*)	(*Grams*)	(*Per Cent*)	(*Per Cent*)	(*Per Cent*)	(*Per Cent of Injected Dose*) **	(*P Values*) ***
					Rats on Low Phosphorus Det ****					
7	7	133	145	12	0.5040 ± 0.0281	54	25	21	0.96 ± 0.09	<0.01
12	6	137	153	16	0.5004 ± 0.0322	54	27	20	0.67 ± 0.06	<0.01
14	4	156	194	38	0.5972 ± 0.0352	57	26	17	0.53 ± 0.07	<0.01
30	6	131	152	21	0.5212 ± 0.0723	52	29	19	0.41 ± 0.03	<0.01
54	5	141	215	74	0.6070 ± 0.0419	53	27	20	0.21 ± 0.03	<0.01
					Rats on Low Phosphorus Diet ****, Sr^{90}-Injected *****					
1	4	141	141	0	0.4391 ± 0.0577	54	23	23	1.31 ± 0.19	>0.05
7	6	154	118	−36	0.5056 ± 0.0494	52	25	23	1.15 ± 0.09	<0.05
14	6	133	139	6	0.4370 ± 0.0507	47	30	23	0.77 ± 0.08	<0.01
30	4	147	172	25	0.5535 ± 0.0334	48	32	21	0.55 ± 0.20	<0.01
54	4	152	179	27	0.5134 ± 0.0632	43	34	23	0.41 ± 0.10	<0.01

* The data from 13 rats were not available owing to death or sacrifice of the animals.

** Figures are mean values and standard deviations.

*** See Footnote a and Table II-A. The P values for the differences between the Sr^{90}-injected and non-injected rats on the low phosphorus diet are <0.05 at seven days, <0.01 at fourteen days, >0.05 at thirty days, and <0.05 at fifty-four days.

**** This diet, containing 0.017 per cent phosphorus, was supplemented after two weeks with additional phosphorus to a level of 0.05 per cent.

***** Sr^{90} dose was 3.2 microcuries per gram of body weight.

cent of the injected dose. Twenty-four hours after injection, 3.64 per cent of the injected dose of Sr^{90} was found in the femur (Skeleton, Table III and Chart IV). Fifty-four days later 2.63 per cent of the dose remained, 1 per cent having been mobilized. Since the ratio of Sr^{90} in the femur to that in the total skeleton is approximately 0.05 [24], an estimated 20 per cent of the injected dose of Sr^{90} was removed from the skeleton. During the first seven days after injection there was no measurable loss of Sr^{90} from the femur. Then, during the period from seven to fourteen days 0.086 per cent of the injected dose was mobilized per day, and from fourteen to thirty days the amount mobilized fell to 0.043 per cent per day. Finally, in the interval from thirty to thirty-five days after injection the rate of mobilization dropped below the limits of experimental variation.

Effects of Radiation

Body weight and growth: One of the effects of beta irradiation at the dose level of Sr^{90} employed in this experiment was to cause a loss in body weight of 15 to 20 grams during the first week after injection. Some of the rats continued

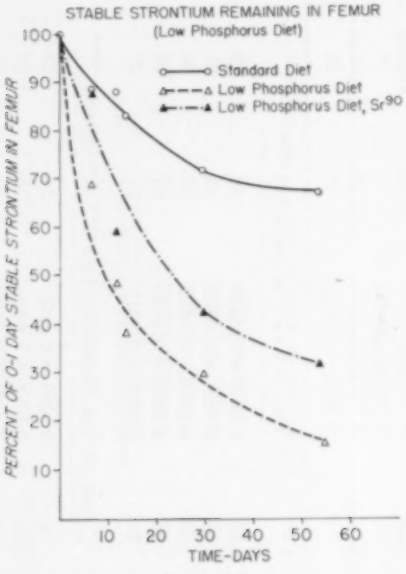

CHART III

to lose weight and either died or were sacrificed between the fourteenth and twentieth days. As noted previously, these animals were eliminated from the final study. The remaining animals injected with Sr^{90} showed a gain in body weight after the first two weeks following injection, even on the phosphorus-deficient diets, although the increase in each case was not nearly so great as for the animals that had not received Sr^{90} (Tables II-A, II-B, and II-C).

Histology: The histological changes in a typical long bone (the tibia) after injection of Sr^{90} at relatively high levels were similar to those described previously [24]. However, histological changes were not confined to the skeleton. There were no apparent changes in the skeletal muscle but changes were apparent in the liver, spleen, and kidneys of the rats that received Sr^{90}. In the liver, the general pattern of hepatic lobules surrounding the central vein was lost. The central veins were small, the endothelium was indistinct, and the hepatic sinusoids were almost obliterated. The nuclei of the hepatic cells were small and pleomorphic and the cytoplasm granular. In the spleen, the lymphatic nodules and the venous

sinuses of the red pulp were smaller and less numerous than normal. The cytoplasm of the cells of both the red pulp and the lymphatic nodules was indistinct, the nuclei were smaller, and the staining of these cells was more eosinophilic than normal. The glomeruli of the kidneys were indistinct and the lumina of the tubules were obliterated. Within the medulla there was decreased vascularity and an increase in the number of fibroblasts between the convoluted and collecting tubules.

Composition of bone (Table II-A): The composition of the femora of the normal rats on a standard diet changed gradually with growth and age. There was an increase in the ash constituents from 23 per cent at forty-two days of age (start of experimental period) to 36 per cent fifty-five days later, and a corresponding decrease in the percentage of water. The percentage of composition of the organic components remained relatively constant during the period under consideration.

Since the rate of increase in femoral weight became slower after injection of Sr^{90}, it seemed appropriate to evaluate the composition of the irradiated

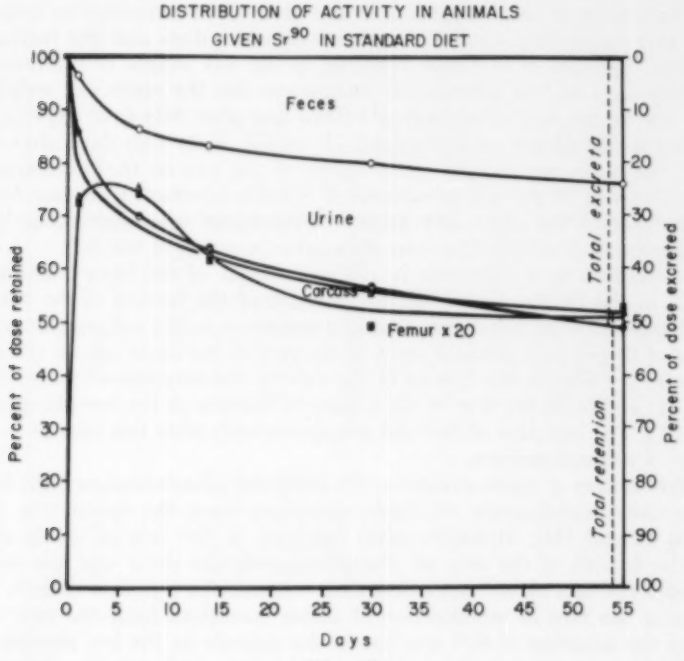

CHART IV

femora on the basis of weight rather than on chronological age. From the wet weight of the femur, the equivalent normal age was determined. Thus, in rats injected with Sr^{90} fifty-five days earlier (ninety-seven days old), the average wet weight of the femur (0.64 grams) was equivalent to the average wet weight of the normal rat femur at sixty days of age. The average ash weight was equivalent to the ash weight of the normal femur at seventy-five days of age. In other words, irradiation from Sr^{90} resulted in a relative increase in ash content in the femur.

Mobilization of stable strontium: To determine the effect of irradiation on the rate of mobilization of inorganic salt from the skeleton, the rate of mobilization of stable strontium from the femora of control rats was compared with that from the femora of rats injected with Sr^{90} (Table II-A and Chart I). There was a significantly slower rate of mobilization of stable strontium in the Sr^{90}-

injected rats than in the controls during the interval from seven to thirty days after injection [a], as determined by comparison of the mean values for stable strontium remaining in the femora in the two groups of animals.

Effects of Phosphorus-Deficient Diets

Body weight and growth (Tables II-B and II-C): Rats maintained on the diet with subminimal (0.21 per cent) phosphorus gained weight more slowly than the animals on the standard diet. Sixty-four days after institution of the diet their weight averaged 40 grams less than that of the animals on the standard diet. The injection of Sr^{90} in the animals receiving subminimal phosphorus caused an initial mean loss in body weight of 36 grams. During the next fifty days these animals regained their initial body weights and continued to gain thereafter, but at the end of the experiment their average weight was still 65 grams less than that of the rats without the injection of Sr^{90}. The body weights of the rats on the low (0.017 to 0.05 per cent) phosphorus diet showed similar changes but these animals were almost cachectic by the end of the experiment. They had to be handled with great care to prevent collapse of the thorax.

Composition of bone (Tables II-B and II-C): The reduction in body weight of the rats maintained on the phosphorus-deficient diets and the further reduction after injection of Sr^{90} were reflected in the wet weight of the femur. After sixty-four days on the subminimal phosphorus diet the mean wet weight of the femur was 96 per cent of normal ($P > 0.05$) and after fifty-four days on the low phosphorus diet 65 per cent of normal ($P < 0.05$). Sixty-four days after injection of Sr^{90}, the mean wet weight of the femur of the rats on the subminimal phosphorus diet was 94 per cent of normal ($P > 0.05$), whereas in the rats on the low phosphorus diet the mean wet weight of the femur was approximately 55 per cent of normal ($P < 0.05$) fifty-four days after injection of the Sr^{90}.

In addition to a reduction in the wet weight of the bone there were also changes in the percentage of ash composition of the femora of the rats on the phosphorus-deficient diets consisting in a reduction in the ash component from a normal of 37 per cent in the femora of the rats of the same age on the standard diet to 33 per cent in the femora of the rats on the subminimal phosphorus diet ($P < 0.01$) and to 20 per cent in the femora of the rats on the low phosphorus diet ($P < 0.01$). The injection of Sr^{90} did not appreciably alter this change in the percentage of ash composition.

Mobilization of stable strontium: On both the subminimal and the low phosphorus diets, mobilization of stable strontium from the femur was increased (Charts II and III). However, after injection of Sr^{90} loss of stable strontium from the femora of the rats on phosphorus-deficient diets was less rapid than that from the rats on corresponding diets without the injection of Sr^{90}. This difference in the rate of mobilization of stable strontium from the rats with and without the injection of Sr^{90} was less in the animals on the low phosphorus diet than in those on the subminimal phosphorus diet. Although the differences between individual autopsy groups on the low phosphorus diet were smaller, comparison by means of paired samples revealed a definite trend toward delayed mobilization following injection of Sr^{90}.

Mobilization of radioactive strontium (Table III and Charts V and VI): Loss of Sr^{90} from the skeleton (percentage of dose in the femur multiplied by 20) on the standard diet during the first thirty to thirty-two days after injection was approximately 24 per cent of the injected dose ($P < 0.01$). The corresponding

a. For each group of rats, the numerical differences between the mean values for stable strontium found in the femur were small. To determine whether differences between groups were real or due to chance, data from the groups were compared by the t test. Differences were assumed to be *significant* if the probability (P) of their occurrence through chance alone was less than one in a hundred ($P < 0.01$); *probably significant* when the P values were between 0.01 and 0.05 ($P < 0.05$); and *not significant* when the values for P were greater than 0.05 ($P > 0.05$).

TABLE III

METABOLISM STUDY

Distribution of Sr^{90} After a Single Intraperitoneal Injection

Test Period (Days)	No. of Rats	Mean Dose of Sr^{90} (*Microcuries per Rat*)	Blood Content of Sr^{90} *, ** (*Per Cent of Dose*)	Sr^{90} Retained ** (*Per Cent of Dose*)		Sr^{90} Excreted (*Per Cent of Dose*)			Sr^{90} Recovered (*Per Cent of Dose*)
				Femur	Carcass	Urine	Feces	Total **	
Standard Diet									
1	5	351	0.125 ± 0.021	3.64 ± 0.43	73.0 ± 5.9	15.1	3.2	18.3 ± 3.8	95
7	6	335	0.024 ± 0.004	3.71 ± 0.28	75.2 ± 4.6	11.0	13.9	24.9 ± 5.8	104
14	6	369	———	3.11 ± 0.43	62.6 ± 9.0	18.2	16.6	34.8 ± 7.4	101
30	6	351	0.007 ± 0.001	2.43 ± 0.30	55.9 ± 6.8	23.3	20.1	43.4 ± 10.8	102
55	9	344	0.007 ± 0.002	2.63 ± 0.11	51.6 ± 6.1	26.8	24.3	51.1 ± 9.1	105
Subminimal Phosphorus Diet ***									
1	4	414	———	4.25 ± 0.24	89.5 ± 8.5	——	——	7.4 ± 1.6	101
14	4	400	———	2.85 ± 0.24	57.2 ± 2.4	——	——	———	———
32	3	392	———	2.13 ± 0.15	41.1 ± 4.2	——	——	———	———
64	6	400	———	2.02 ± 0.32	39.3 ± 5.7	——	——	54.6 ± 9.8	93
Low Phosphorus Diet ****									
1	4	453	———	3.79 ± 0.34	66.3 ± 5.3	——	——	20.8 ± 2.1	91
7	6	496	———	3.24 ± 0.27	74.4 ± 14.2	——	——	29.2 ± 8.8	107
14	6	422	———	1.67 ± 0.26	38.5 ± 5.4	——	——	60.8 ± 10.8	101
30	4	466	———	0.88 ± 0.36	12.5 ± 2.8	——	——	———	———
54	4	483	———	0.81 ± 0.33	16.7 ± 3.1	——	——	74.9 ± 11.7	92

* The per cent of dose of Sr^{90} in the total blood volume was calculated from the value obtained per milliliter, using a ratio of 4.6 milliliters of blood per 100 grams body weight [7].

** Figures are mean values and standard deviations.

*** This diet contained 0.21 per cent phosphorus.

**** This diet, containing 0.017 per cent phosphorus, was supplemented after two weeks with additional phosphorus to a level of 0.05 per cent.

TABLE IV

SUMMARY OF Sr^{90} DISTRIBUTION WITHIN THE SKELETON

(Percentage of Dose)

Time after Injection of Sr^{90}	Exchangeable Compartment			Excretory Compartment	Non-exchangeable Bone		Total Skeletal Uptake	
	Skeletal	Non-Skeletal	Total [(1) + (2)]		Estimated [100] − [(3) + (4)]	Calculated $[a \times \int_0^t Bl_t * dt]$	Estimated [F* × 20]	Calculated [(1) + (6)]
(Hours)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
3	50.75	15.68	66.43	4.12	29.45	17.48	80.2	68.23
4	38.25	9.20	47.45	11.0	41.55	46.68	79.8	84.93
5	27.10	9.40	36.50	12.6	50.90	53.47	78.0	80.57
6	20.16	10.50	30.66	13.7	55.64	58.14	75.8	78.30
7	15.58	10.70	26.28	14.3	59.42	60.68	75.0	76.26
8	12.59	11.50	24.09	14.7	61.21	62.38	73.8	74.97
9	9.40	12.50	21.90	15.1	63.00	64.08	72.4	73.48
10	7.31	12.40	19.71	15.4	64.89	65.35	72.2	72.66
11	6.35	11.90	18.25	15.7	66.05	66.63	72.4	72.98
12	5.59	11.20	16.79	16.0	67.21	67.90	72.8	73.49
16	2.99	10.00	12.99	17.0	70.01	72.14	73.0	75.13
20	1.93	8.80	10.73	17.8	71.47	73.62	75.3	75.55
24	1.38	7.60	8.98	18.4	72.62	75.09	76.4	76.47
48	1.13	3.20	4.33	19.8	75.87	79.94	81.0	81.07

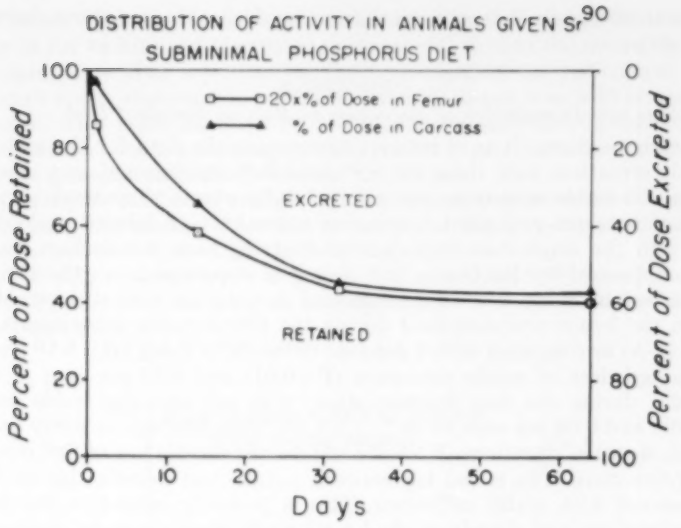

CHART V

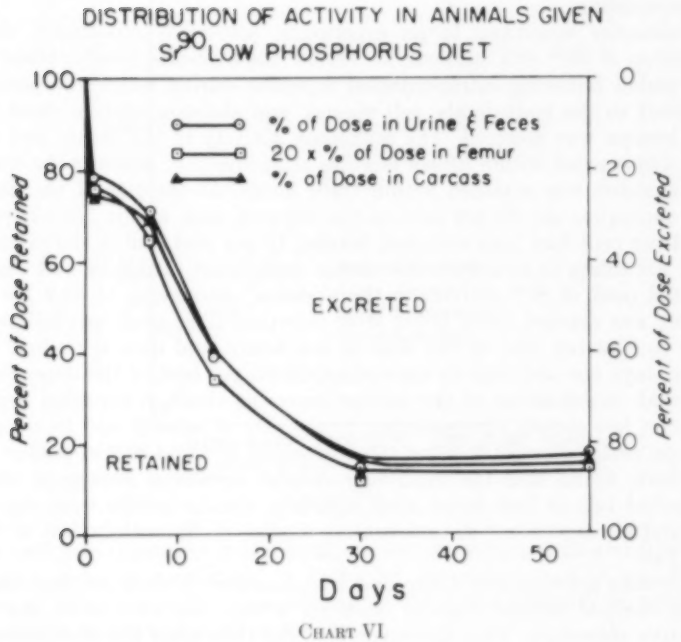
DISTRIBUTION OF ACTIVITY IN ANIMALS GIVEN
Sr90 LOW PHOSPHORUS DIET
% of Dose in Urine & Feces
20 x % of Dose in Femur
% of Dose in Carcass
EXCRETED
RETAINED
Percent of Dose Retained
Percent of Dose Excreted
Days

CHART VI

figure for the rats on the subminimal phosphorus diet was 42 per cent ($P<0.01$), and for the animals on the low phosphorus diet 58 per cent ($P<0.01$). Mobilization of Sr^{90} after the first thirty days was negligible in all groups of rats.

The average loss of Sr^{90} from the carcass (100 per cent of the dose minus the percentage of dose retained) after thirty days on the various diets followed the loss calculated for the skeleton from the data on the femur: 44 per cent loss on the standard diet ($P<0.01$), 59 per cent on the subminimal phosphorus diet ($P<0.01$), and 87 per cent on the low phosphorus diet ($P<0.01$). Little or no

additional Sr^{90} was mobilized from the carcass during the last thirty days on any of the diets.

DISCUSSION

Metabolism and Distribution of Strontium in Rats on Standard Diet

Stable strontium: It is of interest to compare the data for the mobilization of stable strontium with those for Sr^{90} since Sr^{90} was injected as a single dose, whereas the stable strontium was injected daily over a three-week period. The difference between prolonged continuous exposure to a labeled molecule compared with the single-dose technique in studying bone metabolism was previously emphasized by Buchanan and Nakao in experiments on the turnover of bone carbonate. In our rats on the standard diet, 0.5 per cent of the stable strontium in the femur was mobilized during the fifty-five-day experimental period (Table II-A) as compared with 1 per cent of the Sr^{90} (Table III): 0.16 per cent of the injected dose of stable strontium ($P<0.01$) and 0.53 per cent of the Sr^{90} ($P>0.05$) during the first fourteen days; 0.20 per cent for stable strontium ($P<0.01$) and 0.68 per cent for Sr^{90} ($P<0.05$) from fourteen to thirty days; 0.02 per cent of stable strontium ($P>0.05$) and no measurable loss of Sr^{90} from thirty to fifty-five days. The initial lag between uptake and mobilization of Sr^{90} was not observed with stable strontium. This is probably related to the fact that stable strontium had already reached a relatively steady state of turnover compared with the changing state of Sr^{90} in those areas of the skeleton undergoing rapid remodeling.

Radioactive strontium: In an experiment previously reported [24], the early distribution of Sr^{90} was studied. To review these results briefly, there was an initial period following intraperitoneal injection during which the isotope was distributed to the body fluids, soft tissues, and skeleton while a small fraction of the isotope was excreted. The maximum activity in the serum and the soft tissues was reached within fifteen minutes after injection, whereas the maximum in the skeleton was attained within three hours. At the end of the first three hours, approximately 80 per cent of the injected dose was in the skeleton and about 4 per cent had been excreted, leaving 16 per cent still in the extraskeletal tissues. According to data from the current experiment (Table IV and Chart IX), the initial peak of Sr^{90} activity in the skeleton, amounting to 80.2 per cent of the dose, was reached three hours after injection. This peak was followed by a decline to 72.2 per cent of the dose at ten hours, and then a gradual increase between days one and four to approximately 86 per cent of the dose. Following this period, mobilization of the isotope from the skeleton exceeded deposition, the rate of loss closely corresponding to the rate of urinary and fecal excretion.

Copp and associates [13], using tracer doses of Sr^{89} and Sr^{90} in studies of bone metabolism, found that the maximum skeletal uptake of isotope in adult rats was reached two to four hours after injection. Similar results were reported by Bauer and his associates [5] in comparative studies of the metabolism of Sr^{90} and Ca^{45} in rats.

In young growing rats Copp and his coworkers [13] observed that the initial peak in skeletal isotope content occurred within one hour after injection of radioactive strontium. This discrepancy in the time after injection required for maximum uptake of the isotope (one hour in one instance and three hours in the other) may have been caused by differences in the accuracy of sampling and counting, differences in the age and nutritional state of the animals, different dose levels of isotope, and variations in the rate of decrease of activity in the blood, which were related to differences in the rate of excretion and in the rate of turnover of bone mineral. With regard to the differences in the rate of turnover of the mineral Copp and his associates [13], in another phase of their study, reported that the maximum skeletal uptake of isotope and the time required to reach this level were similar in young rachitic rats on a phosphorus-deficient

diet and in normal rats. However, after this initial period, the skeletal content of isotope in the rachitic rats decreased more rapidly than in the normal animals. Twenty-four hours after injection less than one-third of the radioactive strontium present in the skeleton of the rachitic animals at one hour still remained in the skeleton. This rapid turnover of isotope was accompanied by an increased urinary excretion which, according to these authors, may have been due to the effect of the phosphorus-deficient diet on the kidney.

Employing the method of analysis used in a previous experiment ($C_t = \Sigma_n C_i e^{-k_i t}$) [24], the curve for the serum level of Sr^{90} over the fifty-five-day period of these experiments can be described by the following equation:

$$C_t(serum) = 4.5e^{-15t} + 0.30e^{-1.96t} + 0.082e^{-0.25t} + 0.0097e^{-0.0016t}$$

The "fall off" curve for the skeleton starting at seven days can be described by the following equation:

$$C_t(bone) = 55.0e^{-0.18t} + 60.6e^{-0.0013t}$$

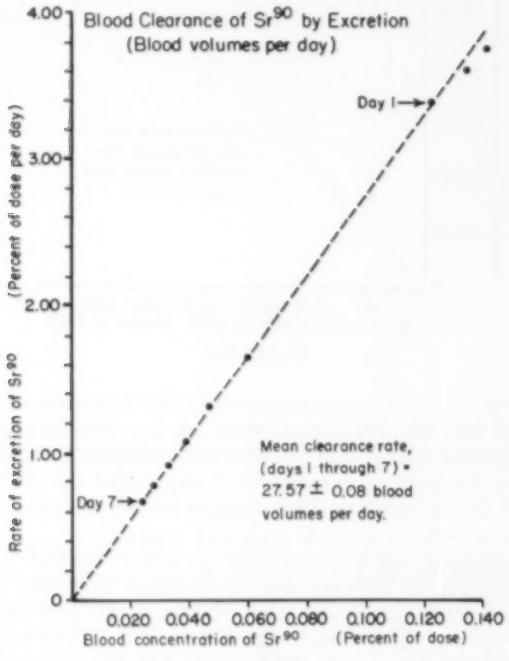
Blood Clearance of Sr90 by Excretion
(Blood volumes per day)
Day 1
Day 7
Mean clearance rate, (days 1 through 7) = 27.57 ± 0.08 blood volumes per day.
Rate of excretion of Sr90 (Percent of dose per day)
4.00
3.00
2.00
1.00
0
0.020 0.040 0.060 0.080 0.100 0.120 0.140
Blood concentration of Sr90 (Percent of dose)

CHART VII

The last two rate constants in the equation for the serum, 0.25 and 0.0016, are of the same order of magnitude as those for the skeleton—0.18 and 0.0013[b]. However, an objection to this type of analysis lies in the difficulty in relating the rate constants to physiological processes.

Another approach has been to correlate the rate of fall in serum activity with the rates of excretion and skeletal gain of isotope [3,4,6]. Detailed development and discussion of the theory, together with the assumptions and mathematical analyses involved, are beyond the scope of this paper, but a summary is pertinent to this discussion.

From a theoretical standpoint, bone-seeking isotopes may be incorporated

b. The rate constant, k, is the fraction of the total amount of the substance (labeled and unlabeled) replaced per unit of time, that is, $k = r/M$, where r is the rate and M the total amount of substance in question.

into living bone by two different processes: exchange and accretion. Exchange may be regarded as a reversible process, operating between the body fluids and the bone salt, in which there is no net gain or loss in the total amount of salt present in the bone: the ions leaving the body fluids to enter the solid phase of the bone salt displace an equal number of ions that simultaneously leave the bone salt to enter the body fluids. In this process neither the amount nor the configuration of the bone-salt crystals undergoes any change. Accretion of bone mineral may be defined as crystal formation and growth. Under normal circum-

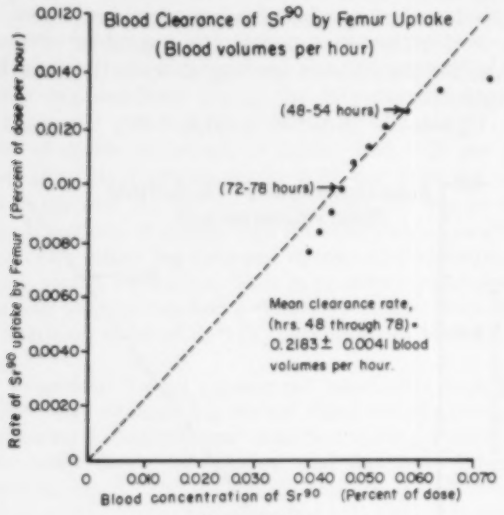

CHART VIII

stances accretion is preceded or accompanied by the formation of organic matrix. Ions incorporated into this fraction of bone salt are metabolically trapped and thus removed from the exchangeable pool[c] until released by bone resorption or by exchange. The duration of entrapment is dependent on the life span of the particular part of the skeleton involved, ranging from hours or days in trabecular bone to weeks or months in cortical bone and enamel[5].

When bone-seeking isotopes are used to study skeletal metabolism, the problem is to differentiate between the equilibration processes of exchange, on the one hand, and accretion on the other. To solve this problem four basic assumptions are required: (1) the exchangeable fraction of the bone salt must be in rapid equilibrium with the body fluids, that is, the "mixing" time after introduction of the isotopes into the body must be relatively short compared with other processes of distribution; (2) at equilibrium the isotope must be uniformly distributed in the exchangeable space or compartment[c]; (3) there must be a significant interval of time between accretion and the onset of mobilization—a minimum metabolic time lag before accreted isotope begins to return to the body fluids; and (4) the system under investigation must be in a steady state with regard to everything except the concentration of the isotope during the experimental period, that is, the volume of the exchangeable space must remain constant, and the rates of loss of isotope from the exchangeable pool by excre-

c. The word *pool* refers to the amount of a given substance, in mass units held within a space or compartment. The words *space* and *compartment* are used interchangeably to designate distinguishable phases or volumes within which the components of living systems may be located[29]. The limits of these phases or volumes may or may not correspond to anatomical boundaries. For example, the cerebrospinal fluid is enclosed within a fairly clearly defined compartment. In contrast, the calcium space, although it is more difficult to localize, is no less clear in concept[27].

tion and skeletal accretion must also be constant. When isotopes are used to study bone metabolism, the following may be determined directly: the amount of isotope injected, the concentration of isotope in the blood, the loss by urinary and fecal excretion (Chart VII), and (in animal studies at least) the total uptake of isotope by bone through exchange and accretion (Chart VIII). Granting the assumptions previously mentioned, two unknowns still remain: the volume of the miscible pool or exchangeable compartment in which the isotope is distributed and the rate of loss of isotope from this pool by skeletal accretion. There are at least three ways to solve these unknowns.

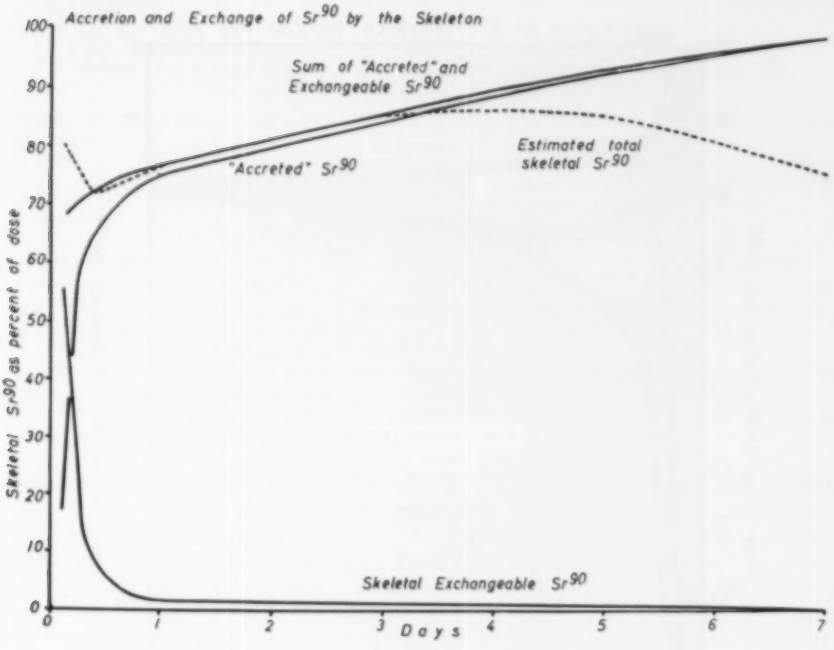

CHART IX

The first method, proposed by Bauer, Carlsson, and Lindquist in 1955[4], is based on the fact that the blood or plasma[d] concentration of isotope after injection rapidly approaches zero, whereas the amount of isotope in bone continues to increase. If one assumes that the isotope in the blood is in rapid equilibrium with the exchangeable fraction of the bone salt, it follows that the isotope in the exchangeable fraction of the bone salt approaches zero during the same time interval that the blood isotope approaches zero. The error introduced by this assumption is probably less than 2 per cent three to four days after injection (Table IV). Furthermore, if it is assumed that no significant amount of isotope has been mobilized by remodeling (the metabolic time lag previously mentioned), the increase in isotope in the skeleton observed during the first three to four days after injection may be regarded as due to accretion. If the skeletal increase of isotope is related to the integrated activity of the blood over the corresponding interval, accretion may be expressed as a blood clearance rate (since stable strontium is not normally present in easily measured amounts in the blood, it is more appropriate to give the values in terms of blood volumes cleared of isotope

d. In a study (unpublished data) of the distribution of Sr^{90} in rat blood, 3.8 ± 1.0 per cent was found in the blood cells and 96.2 ± 1.0 per cent was found in the plasma. This distribution was established within ten minutes after intraperitoneal injection of the Sr^{90} and the distribution thereafter did not change over a forty-eight-hour period.

per unit of time rather than in terms of specific activity or amount of stable element taken up by bone per unit of time). In this experiment, the values obtained by this method were for the rate of loss of isotope from the miscible pool—106.2 blood volumes cleared by skeletal accretion per day and for the volume of the exchangeable space 79.8 blood volumes (Table V).

The second method, suggested by Bauer, Carlsson, and Lindquist [3] and subsequently employed by Bauer and Ray, is based on the elimination of one of the two unknowns, the volume of the exchangeable space, by means of simultaneous equations and solving for the other unknown, the accretion rate. The values

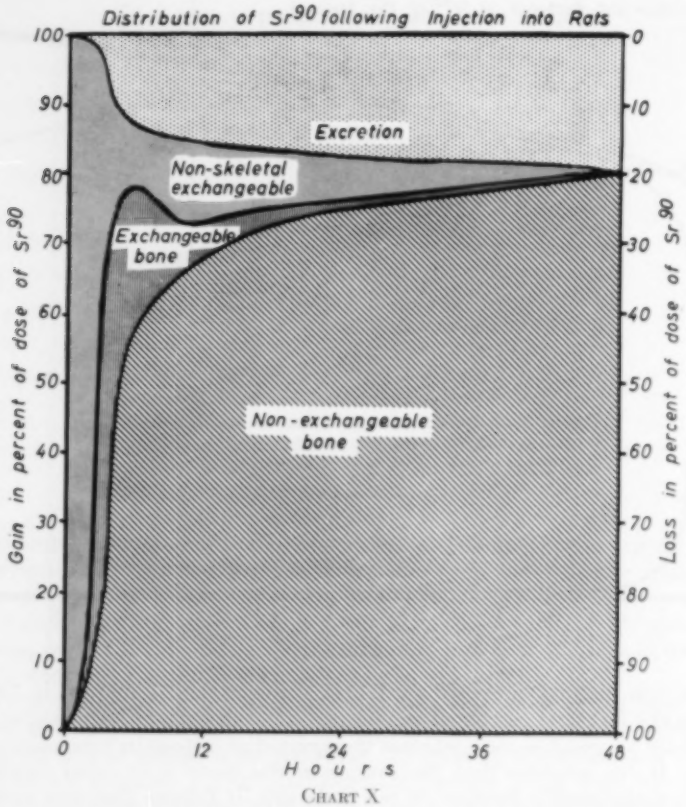

CHART X

determined by this method were for the rate of loss of isotope from the miscible pool—117 blood volumes cleared by skeletal accretion per day and for the volume of the exchangeable space 73 blood volumes (Table V). These values have been used to calculate the data presented in Table IV and to construct the curves in Chart IX and the diagram of Sr^{90} distribution shown in Chart X.

The third method is based on determining the volume of the exchangeable space from the effective concentration of the isotope at zero time. This can be accomplished graphically or mathematically by extrapolating a semilogarithmic plot of the curve for the blood concentration to zero time, using the exponential part of the slope after the initial period of "mixing" or equilibration has passed and before the break in the curve occurs owing to "recycling" of accreted isotope. After the volume of distribution of the isotope at zero time has been determined, the amount of isotope in the exchangeable space at any subsequent time may be calculated from the blood concentration at that time. The accreted isotope may

be computed as a simple difference: Accreted isotope = Injected isotope − (Excreted isotope + Isotope in the exchangeable space). According to this method, the rate of accretion is 108.4 blood volumes per day and the corresponding volume of the exchangeable space is 102.3 blood volumes (Table V). In these calculations it has been assumed that the concentration of isotope in the total exchangeable space is uniform once a steady state is reached. Since this is unlikely, a correction factor must be introduced, a factor estimated at 1.428, based on a calcium ion concentration in the exchangeable space of 70 per cent of that in the plasma [6,18,26]. The corrected value for the volume of the exchangeable space is 71.6 blood volumes, a figure comparable with that obtained with the previous

TABLE V

CALCULATED VALUES FOR THE VOLUME OF THE EXCHANGEABLE COMPARTMENT (E) AND THE RATE OF CLEARANCE BY "ACCRETION" (*a*)

Method *	E	*a*
	(Blood Volumes)	(Blood Volumes per Day)
1 [4]	79.8 **	106.2
2 [3]	73	117
3	102.3	108.4
3 (corrected)	71.6 ***	111.1 ****

* The fundamental principles and assumptions involved in these approaches are described in the text and in the original references.

** Calculated from six-hour data (Table IV).

*** Calculated from 102.3 blood volumes, assuming the calcium ion concentration in the exchangeable compartment to be 70 per cent of that in the plasma.

**** Calculated using 71.6 as the volume of the exchangeable compartment and the data for six and twenty-four hours (Table IV).

method (Table V). However, studies by Engel, Joseph, and Catchpole indicate that dense tissues, such as cartilage, may contain calcium ions in concentrations three times as high as those in blood [e]. Furthermore, the preceding factor, derived from experiments with calcium, may be inappropriate for strontium.

Another point that should be mentioned is that all three of these methods are critically dependent on the interval selected after the injection of the isotope for determining the value for accretion. To meet the assumptions on which the methods are based, mixing and equilibration within the subcompartments of the exchangeable space must have been completed, and resorption or recycling of the isotope must not have occurred. During this interval the rate of excretion of isotope (urinary and fecal) and the calculated accretion rate should bear a constant relationship to the blood concentration of the isotope. From Charts VII and VIII, in which the rates of excretion and uptake of isotope by the femur are plotted against the corresponding blood isotope concentrations, it may be seen that the requisite conditions prevail for only a short period of time.

A final point should be mentioned. Although the methods described can be used to distinguish between rapid uptake of isotope by bone (predominantly

e. These investigators concluded that the Gibbs-Donnan equilibrium and the law of mass action may be used to characterize electrolyte distribution between blood and connective tissue even though calcium concentration is, in part, determined by chemical binding. From these studies, it appears reasonable to assume that the differences in concentration of calcium (and perhaps other bone-seeking elements) in the various spaces or compartments of the body (plasma; the extravascular spaces including both the intracellular and extracellular spaces; and skeletal exchangeable compartment), each expressed as a Donnan factor, may be combined into a single product, the reciprocal of which could be used as a plasma correction factor (f) to determine the volume of the exchangeable pool at zero time (E_o):

$$E_o = \frac{R_o^*}{(f)P_o^*}$$, where R_o^* and P_o^* represent the retained dose and the plasma isotope concentration, respectively, at zero time.

exchange reactions) and slow uptake, it is difficult by isotope techniques to distinguish: (1) between exchange processes slowly reaching a steady state and accretion, and (2) between rapid recycling of isotope caused by accretion—mobilization and exchange. It may be possible to discriminate between exchange and accretion by measuring the rate of formation of organic matrix directly and comparing it with the rate of mineralization. In this connection, studies of the comparative rates of skeletal uptake of Ca^{45} and C^{14}-tagged proline are currently in progress.

Effects of Radiation on Skeletal Metabolism

If radiation has an effect on the mineral metabolism of the skeleton, it should be possible to demonstrate some degree of correlation between the amount of inactive and the amount of radioactive strontium present in the same bone in the rats that received both. Examination of the data reveals that: (1) if the average percentage of the dose of inert strontium found in the femora of rats not injected with Sr^{90} is considered to represent the "normal behavior" of rats on the different diets, and (2) if deviations from this norm are calculated for each animal in the corresponding group of animals that were injected with Sr^{90}, it is found that in some instances there is a high degree of correlation between the "deviation from normal behavior" and the amount of radioactive strontium present.

This is illustrated by the rats on the low phosphorus diet. If the observed percentage of the injected dose of stable strontium present in the femur of each of these phosphorus-deficient animals at fifty-five days is subtracted from the average value for stable strontium in the femora of the non-radioactive controls at fifty-five days and the difference so obtained (the "deviation from normal behavior") compared with the percentage of the dose of Sr^{90} found in the femur, a correlation coefficient of 0.956 is obtained [17]. The correlation coefficients are 0.753 for rats on the subminimal phosphorus diet at sixty-four days and 0.894 for rats on the standard diet at fifty-four days, indicating a strong dependence between the percentage of stable strontium retained and the percentage of Sr^{90} present in the same bone. The correlation coefficients are smaller for rats on the standard and subminimal phosphorus diets prior to fifty-five days, but values of 0.410 at seven days, 0.817 at fourteen days, and 0.963 at thirty days for rats on the low phosphorus diet show that the effect of radiation was apparent after seven days and that it increased rapidly with increasing exposure of the bones to radiation. Thus, it can be concluded that internal beta irradiation of the skeleton at the levels employed in this experiment definitely retarded mobilization of mineral from the skeleton, a conclusion which is warranted regardless of the mechanism involved. However, the changes observed in the skeletal metabolism of these animals, particularly those on the phosphorus-deficient diets, were influenced by factors other than radiation damage to the bones. Radiation changes in other organs, notably the kidneys, were demonstrated in the histological studies. These changes may well have influenced skeletal metabolism. Similarly, inanition must have had some influence since all of the animals receiving Sr^{90} lost weight during the first week after injection of the isotope and over half of those injected died or were sacrificed from fourteen to twenty days later because of cachexia. All of the animals on subminimal and low phosphorus diets weighed appreciably less than the controls, and the animals on the low phosphorus diets were almost cachectic by the end of the experiment.

On the other hand, in a previous experiment [23], comparison was made of the mobilization of Sr^{90} from living bone with that from dead bone (killed by rapid freezing and then reimplanted in the animal). The results of this study showed that the death of the cells resulted in retarded mobilization of minerals from bone, a finding that suggests that the metabolic changes observed in the current experiment were, in part at least, the result of bone-cell damage. Whether the

radiation damaged the bone cells directly or indirectly by altering the circulation or whether both mechanisms were involved in the present experiment could not be determined from the data. The work of other authors dealing with this problem [10,15,19,22,28,30] suggests the operation of at least two primary factors: (1) direct radiation injury to the bone and cartilage cells, and (2) injury to bone blood vessels with subsequent ischemia.

Effects of Phosphorus-Deficient Diets on Strontium Mobilization

Even though the mobilization of mineral from the skeleton was retarded in the presence of radiation damage, diets deficient in phosphorus in these animals were still effective in accelerating the mobilization of both stable strontium (Charts II and III) and Sr^{90} (Charts V and VI). After approximately sixty days the increase in mobilization of stable strontium was 44 per cent of the injected dose on the subminimal phosphorus diet ($P<0.01$) and 72 per cent on the low phosphorus diet ($P<0.01$) (Tables II-A, II-B, and II-C). The body burden of Sr^{90} at the end of the experimental period was reduced by approximately 29 per cent of the injected dose on the subminimal phosphorus diet ($P<0.01$) and 81 per cent on the low phosphorus diet ($P<0.01$) (Tables II-A, II-B, and II-C). The effect of increased mobilization of strontium was most pronounced between seven and thirty days after institution of the phosphorus-deficient diets. This finding suggests that: (1) there is a lag period which must elapse before the body reserves of phosphorus are depleted, and (2) there is a limit, probably imposed by the degree of radiation damage, beyond which phosphorus-deficient diets are no longer effective in mobilizing mineral from the skeleton. There also is a limit beyond which the animal cannot survive on a diet so deficient in phosphorus, as pointed out by Copp and associates [13]. A possible further limitation on the effectiveness of phosphorus-deficient diets in the mobilization of Sr^{90} is the additional radiation damage to the kidney which might result from accelerated mobilization and increased urinary excretion of the isotope. Despite these limitations and the fact that most of the strontium in the skeleton had been removed from the exchangeable pool by the time the diets became effective, it was still possible to accelerate the mobilization of an appreciable fraction of the previously-deposited isotope by decreasing the dietary phosphorus. This conclusion—based on the studies presented here, as well as on those of Copp and associates [13], already discussed—seems to contradict the statement of Boyd and his associates [9]. Based on *in vitro* studies of long-term strontium exchange, these workers stated that procedures for the reduction of a skeletal burden of radioactive strontium are likely to be unsuccessful since, apparently, the strontium ions become buried by physical and physiological processes and thereby are out of reach of any attempts at mobilization. It is noteworthy that even though strontium ions become buried within the bone crystals after a single injection of Sr^{90}, bone resorption and mobilization of the inorganic salt can still be induced by low phosphorus diets, presumably as long as there remain a sufficient number of viable bone cells and adequate circulation of blood to the bone.

SUMMARY

1. Two hundred male Long-Evans rats, weaned at twenty-one days of age, were injected daily with stable strontium for twenty-one days. Stable strontium was then discontinued and approximately half of the total number of rats received a single sublethal injection of Sr^{90}. The metabolism of Sr^{90}, the effects of radiation damage on the mineral metabolism of bone, and the effects of phosphorus-deficient diets on the mobilization of both stable strontium and Sr^{90} from bone were studied for fifty-four to sixty-four days after injection.

2. After a single injection of Sr^{90}, the initial rapid rise in plasma activity is succeeded by a rapid decline. An attempt was made to correlate the changes in plasma activity with the rates of excretion and of skeletal uptake of the isotope.

3. Mobilization of stable strontium from bone was delayed in rats that received Sr^{90}.

4. Diets deficient in phosphorus became effective in increasing the mobilization of both stable strontium and Sr^{90} from bone seven days after the diets were instituted. However, thirty days after the administration of the isotope the diets became relatively ineffective in mobilizing mineral in the Sr^{90}-injected rats.

5. It appears that the effectiveness of phosphorus-deficient diets in accelerating bone resorption is dependent on the presence of an adequate number of viable bone cells and adequate circulation to the bone, both of which may be affected by exposure to radiation at the dosages of Sr^{90} employed in this experiment.

Note: The authors would like to express their appreciation and indebtedness to the many people who have contributed to and participated in this study during the past six years. In particular, the authors would like to recognize the contributions made by Dr. Goran C. Bauer, Dr. Norvelle K. Wolff, and Dr. Duane F. La Violette.

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(*Continued on page 858*)

Luschka's Joint—A Degenerative Phenomenon*

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The presence of a joint with a synovial lining between the opposing superior and inferior margins of adjoining cervical vertebrae has been the subject of discussion since Luschka first described and illustrated joints of this type in these locations. Since that time they were also described by Boreadis and Gershon-Cohen and by Jackson. Compere and associates estimated the dimensions of these joints to range from two by four to three by six millimeters. In contrast, Frykholm believed these so-called joints to be fissures produced by degeneration

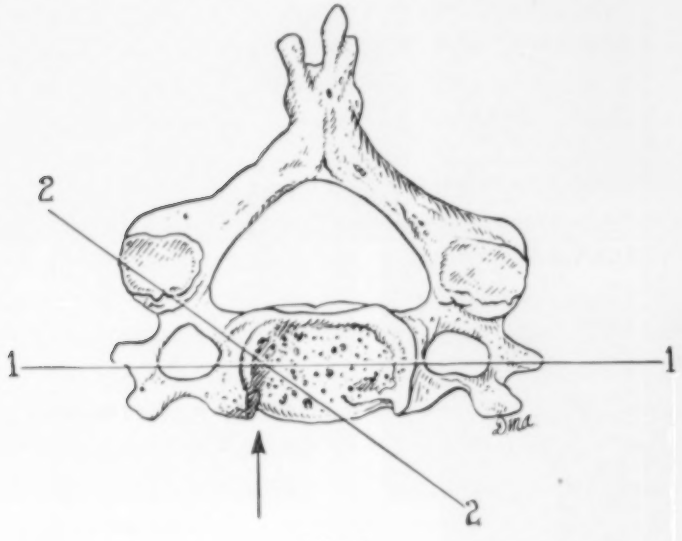

FIG. 1

Diagrammatic representation of cervical vertebra to show planes of sections: line *1,1* is the plane of the coronal section; the oblique plane of the section is shown by line *2,2*. The uncinate process and supposed area of Luschka's joint are indicated by the dark shading and the arrow.

of the disc substance. He stated that disc tissue extends to the margins of the vertebral bodies. This view was shared and supported by the anatomical studies of Bovill and Drazek and of Payne and Spillane. Hadley was unable to demonstrate a true synovial joint in this region. He noted that the outward projecting lips at the lateral margins of the superior surface of each vertebral body are separated from the body of the vertebra above by a space that is less than one-third the normal height of the disc. He considered this to be of great importance and he postulated that the decrease in the height of the disc that accompanies degeneration of the disc forces the uncinate processes up and out to produce the char-

* Presented at the Annual Meeting of the Orthopaedic Research Society, Chicago, Illinois, January 23, 1960.

FIG. 2-A

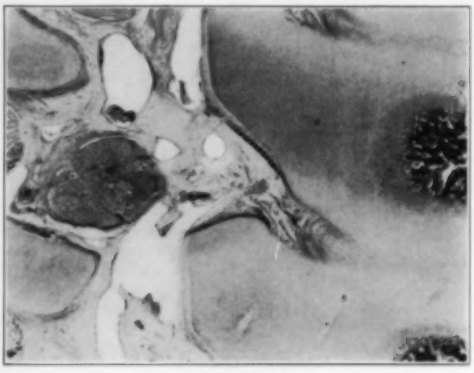

FIG. 2-C

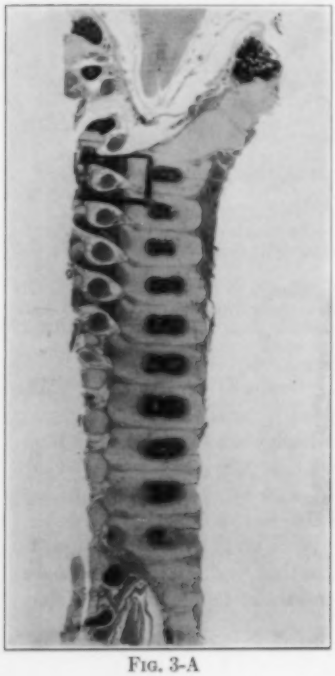

FIG. 3-A

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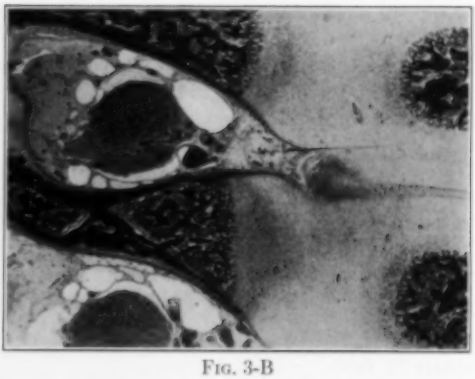


FIG. 3-B

Fig. 2-A: Coronal section of a fourteen-centimeter fetal spine from the base of the skull to the thoracic vertebrae. This demonstrates the general relationship of the intervertebral discs to the uncinate processes and the lateral vertebral margins. The areas selected for magnification are indicated.

Fig. 2-B (upper right): Coronal section of the true synovial joint between the first and second cervical vertebrae, showing a well developed synovial membrane.

Fig. 2-C: Coronal section through the region about the uncinate process, showing the lateral margin of the annulus fibrosus, the cephalad projection of the uncinate process, and the loose fibrous tissue with many blood vessels lying between the uncinate process and the inferior margin of the vertebral body above.

Fig. 3-A: Oblique section of the cervical spine of a thirteen-centimeter fetus from the base of the skull to the thoracic vertebrae, showing neural foramina, each containing a cervical nerve and ganglion. The area of magnification is indicated.

Fig. 3-B: Oblique section through a neural foramen, magnified approximately twenty times, showing the nerve lying in the center of the foramen. In the upper left-hand corner the lining of the synovial membrane of the apophyseal joint can be seen. Again, the area between the uncinate process of the cervical vertebra and the inferior margin of the vertebra above is filled by loose fibrous tissue and a large number of blood vessels.

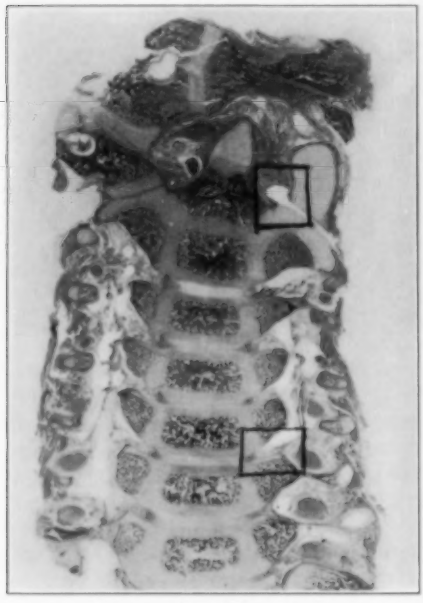


FIG. 4-A

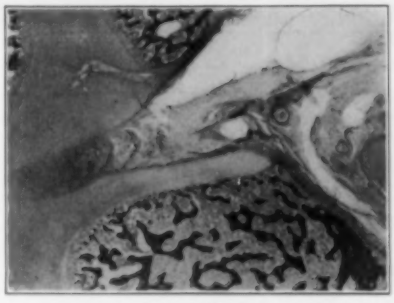


FIG. 4-C

Fig. 4-A: Coronal section of the cervical spine of a full-term fetus. The areas chosen for magnification are demonstrated.

Fig. 4-B (upper right): Coronal section through the true synovial joint between the first and second cervical vertebrae showing its well developed synovial membrane.

Fig. 4-C: Coronal section through the region of the uncinate process of the fifth cervical vertebra showing the proximity of the cervical nerve and loose fibrous tissue with many blood vessels which underlie and separate the nerve from the vertebral body and its processes.

acteristic roentgenographic picture and the formation of osteophytes. That the spaces are of degenerative origin is also suggested by Luschka's description of their formation in early adult life.

The essential structures of the musculoskeletal system are present in forms resembling those of the adult by the third or fourth month of fetal life [1,7]; more specifically, by the seventh or eighth week of gestation practically all structures of the extremities, including those of the joints, are formed in arrangements characteristic of the adult, although the synovial tissue itself is not clearly recognizable until approximately the tenth or eleventh week of gestation. To avoid artefacts and degenerative phenomena a study of the cervical spine, start-

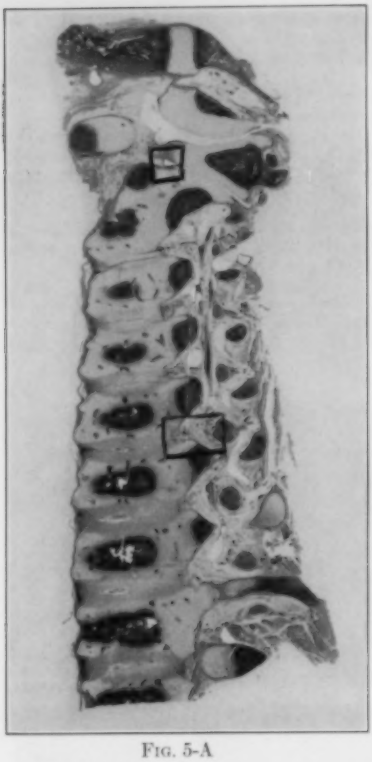
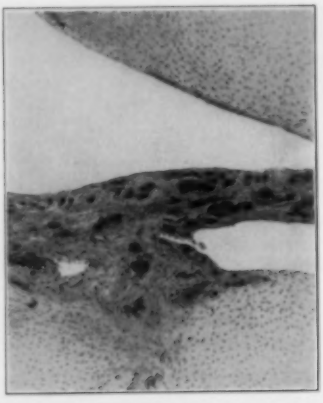


FIG. 5-A



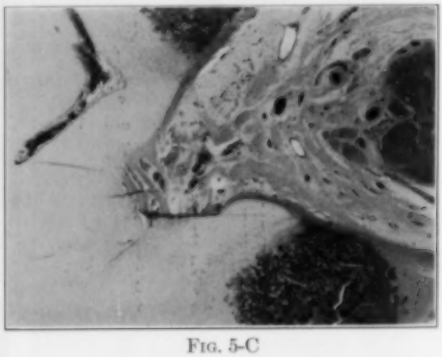


FIG. 5-C

FIG. 6-A

(Legends at top of page 857)

FIG. 6-B

Fig. 5-A: Oblique section of the cervical spine of a 130-millimeter fetus of approximately four and one-half months' gestation, showing areas which were chosen for magnification to demonstrate the morphology in the region of the uncinate process, and also of a true joint of the cervical spine.

Fig. 5-B (upper right): Joint between the first and second cervical vertebrae with a well developed synovial membrane.

Fig. 5-C: Area of the uncinate process with its surrounding loose fibrous tissue containing many blood vessels. Again, the annulus fibrosus is seen to end at the base of the uncinate process.

Fig. 6-A: Coronal section of the spine of an elderly adult, showing pronounced osteophytic reaction. The area chosen for magnification is indicated.

Fig. 6-B: This is the region of an uncinate process of an adult showing the formation of reactive new bone that causes upward and lateral projection of the uncinate process. The fibrocartilage in this area appears to be reactive and is laid down in an extremely haphazard manner. The clefts in this irregularly arranged fibrocartilage can be clearly seen; they simulate joint spaces. However, no vestige of a synovial membrane lining is seen. This specimen was preserved by freezing and several of the tissue clefts are artefacts due to this.

ing during this period of prenatal development, was undertaken using the cervical spines from a thirteen-centimeter and a fourteen-centimeter fetus, eight full-term fetuses, and one elderly adult. Coronal and oblique longitudinal sections of the cervical spine were made (Fig. 1).

In the coronal section of the cervical spine of the thirteen-centimeter fetus, the uncinate processes from the third to the seventh cervical vertebrae are separated from the vertebrae above by loose fibrous tissue (Fig. 2-A). The annulus of the disc is seen to terminate at the base of this process. A well formed joint with a synovial lining is clearly visible between the first and second cervical vertebrae (Fig. 2-B). In the region of the uncinate process (Fig. 2-C) no synovial membrane is present and the architectural detail of the intervertebral area can be seen more clearly. In the oblique section of the cervical spine of the fourteen-centimeter fetus the uncinate processes of the third to seventh cervical vertebrae again are demonstrated (Fig. 3-A). A section through the neural foramen clearly demonstrates a synovial lining in the apophyseal articulation, but no such lining exists in the region of the uncinate processes (Fig. 3-B). The nerve in this region is surrounded by numerous blood vessels. Coronal and oblique sections of four full-term cervical spines (Figs. 4-A and 5-A) fail to demonstrate a synovial membrane in the region of the uncinate process (Figs. 4-C and 5-C), but clearly show that the annulus does not extend outward to the vertebral margins but leaves a space between the uncinate process and the vertebra above which is filled with loose fibrous tissue and many blood vessels. Figures 4-B and 5-B show the well developed synovial membrane between the first and second cervical vertebrae of the full-term fetus in the coronal and oblique sections, respectively. The coronal section of the cervical spine of an elderly adult shows clearly the fissures and clefts in the region of the uncinate process (Fig. 6-A). The area which once was filled with loose fibrous tissue is now filled both with fibrocartilage arranged in an extremely haphazard fashion and with new bone that protrudes upward and outward. One of the least involved areas in this spine was chosen for magnification; it clearly demonstrates that the lipping seen roentgenographically is a reactive osteogenic process and not the result of calcification of a protruded disc or of degenerative arthritis (Fig. 6-B).

This study indicates that no synovial joint exists in the region of the uncinate processes of the cervical vertebrae and that the changes seen in roentgenograms and described as being due to degenerative arthritis or protruded intervertebral discs are due to reactive osteogenesis, or what Bick called osteophytosis. This new-bone formation is a response to the repeated minor stresses of aging that result in collapse of the intervertebral disc [1, 8]. The process is perhaps hastened by external trauma of varying severity [9].

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Tonic Reflexes of the Foot

Their Orthopaedic Significance in Normal Children and in Children with Cerebral Palsy*†

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Certain tonic reflex movements of the foot are worthy of orthopaedic interest, for they are a potential cause of deformity. These reflexes are easily elicited at birth and normally disappear in an orderly sequence during the first years of life. If one or more reflexes fail to disappear, a reflexly induced deformity may occur. The concept of reflexly induced deformity is that if a reflex movement repeatedly occurs, the involved structures will eventually assume the distorted attitude produced by the reflex movement, and a contracture develops. Such deformities are more common in patients with cerebral palsy in whom disappearance of these reflexes is frequently delayed, but they are also observed in essentially normal infants during the first year of life. Recognition and management of these deformities require understanding of the reflexes, including the areas of elicitation, adequate stimulus, and the pathway of the reflex arc.

Reflex movements of the foot in response to cutaneous stimulation have been observed in the human fetus at the eleventh week of menstrual age [11]. By the fourteenth week, the majority of reflexes encountered in the neonate are readily obtainable. In the first hours and days after birth there is a rapid diminution of reflex activity [5] that continues at a lesser rate until, by the end of the first year, superficial reflex activity cannot be elicited by ordinary means of stimulation. The disappearance of superficial reflex activity of the foot is presumed to be due to a suppression accomplished by the maturing cerebral cortex [3] because removal of certain areas of the cerebral cortex causes the return of previously suppressed reflexes. In children with brain damage the suppressive ability of the cortex is evidently impaired, since superficial reflex activity of the foot may persist throughout childhood.

The term tonic is employed because these reflex movements occur slowly, as though tonus or tension was accumulating, in contrast to the abrupt phasic response of a tendon jerk. These reflex movements are patterned responses requiring coordinated participation of several muscles. There is a compulsive quality of the movement that prevails despite the patient's obvious efforts to resist. Tonic reflexes are characterized by a substantial latent period (one to three seconds) between the initial stimulus and the responsive movement. They are superficial reflexes in that they are elicited by stimulation of the skin alone. Four tonic reflexes of the foot are recognized:

1. The toe-grasping reflex (Fig. 1-A) is a flexion and adduction of the toes in response to stimulation of the ball of the foot, near the base of the second and third toes. Since Barraquer's original description in 1921, the many interesting features of the toe-grasping reflex—its presence in normal infants [4], persistence in children having mongolism [4], reappearance in monkeys after premotor lesions [12], similarity to the grasping reflex of the hand [14], and its function as part of the righting reflex mechanisms [12]—have been the subject of considerable investigation and of excellent reviews [3,9,14].

* Read in part at the Annual Meeting of the Western Orthopedic Association, Portland, Oregon, October 24, 1958.

† Supported in part by a grant from the Orthopedic Research Foundation of Seattle.

2. The inversion reflex * (Fig. 1-B) is a tonic inversion of the foot in response to stimulation of the medial border of the foot near the head of the first metatarsal. The prime movers appear to be the anterior and posterior tibial muscles. Flexion or extension of the toes is variable. The toes usually deviate toward the medial border of the foot.

3. The eversion reflex * (Fig. 1-C) is an eversion of the foot in response to stimulation of the lateral border of the foot over the head of the fifth metatarsal and the base of the little toe. Primary muscle activity is observed in the peroneals, principally the peroneus brevis. The toes often deviate toward the lateral border of the foot with a fanning effect. Flexion or extension of the toes is variable.

4. The dorsiflexion reflex * (Fig. 1-D) is a dorsiflexion of the foot in response to stimulation of the central portion of the plantar surface of the heel. The prime mover is the tibialis anterior. The extensors of the toes frequently participate. The similarity of this reflex to the dorsiflexion movement that occurs in the triple-flexion response is evident; however, the frequently observed associated extension of the hip and knee is in distinct contrast to the flexion of the hip and knee that occurs in the triple-flexion response.

METHOD

The children included in this study came from the Children's Orthopedic Hospital, the Boyer Avenue Spastic Preschool and Clinic, and the Warren Avenue Spastic School, where I have had the opportunity to supervise orthopaedic care. One hundred and fifty children, of all ages, with cerebral palsy were available for periodic study. Fifty normal subjects and eight patients with spinal paraplegia (three children, five adults) were also observed in the hospital wards and in private practice.

The ultimate adequate stimulus for these reflexes is not understood. In the newborn, the lightest touch on the ball of the foot is sufficient to produce the toe-grasping reflex [4,13]. This form of stimulation, although equally adequate in the neonate for the other three tonic reflexes of the foot, rapidly loses its effectiveness during the first months of an infant's life. It is then that the value of a summated stimulus becomes evident. Digital stroking and brushing, although useful, do not afford a continuous uniform stimulus on which to base day-to-day observations. A small electrical massage vibrator † fitted with a soft sponge-rubber applicator was finally selected for these studies. During operation, the applicator moves a few millimeters across (or with) the skin sixty times per second. The impact of the stroke is comfortably low. The effect of this vibratory stimulator is not confined to the skin alone, but is transmitted for some distance through the underlying tissues. If applied directly over the belly of a spastic muscle, the stimulator may induce a contraction of the muscle; this possibility does not impair its usefulness as a surface stimulator but does demand critical interpretation of any movements induced.

During the testing, each patient was recumbent, with the feet extended over the edge of the examining table. Visual stimulation [6] was allowed, in as much as no blindfold or shield was used. The sponge applicator of the vibrator was held gently against the reflexogenous area and moved with the foot as the reflex movement occurred. Stimulation was continued until the reflex ceased and the foot moved away from the stimulator. The duration (in seconds) of the reflex was recorded. No attempt was made to record movement that persisted longer than thirty seconds.

* The descriptive terms, inversion, eversion, and dorsiflexion, were selected by me in 1955, in the absence of prior reference. The selection was made in keeping with the suggestion of Wartenburg that reflexes should be named on the basis of the reflex movement evoked rather than on the point of stimulation. The recent publication of Fradis and Botez employs the terms "medial groping" and "lateral groping" to describe, perhaps more aptly, movements similar, if not identical, to what I call the inversion and the eversion reflexes. However, the functional significance of these motions may be other than that of groping.

† Andis Vibrator, Type A.V., 110 volts, 60 cycles, 15 watts.

FIG. 1-A

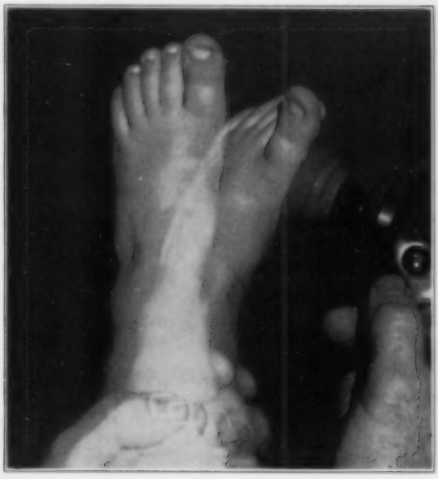

FIG. 1-B

FIG. 1-C

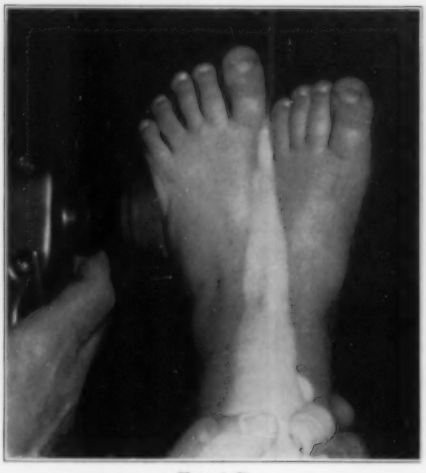

FIG. 1-D

Figs. 1-A through 1-D: Four tonic reflexes of the foot. Shadow views made with exposure before and during application of the vibratory stimulator.
Fig. 1-A: Toe grasping.
Fig. 1-B: Inversion.
Fig. 1-C: Eversion.
Fig. 1-D: Dorsiflexion.

It is also possible, although less comfortable for the patient, to obtain these reflexes by electrical stimulation. Several patients were tested with a Sanborn stimulator, with which various frequencies and pulse widths to the reflexogenous area through bipolar skin electrodes were applied. The optimum pulse duration was one millisecond.

The optimum frequency of seventy per second corresponds favorably with that of the test vibrator and with optimum frequencies for direct electrical stimulation of muscle [7].

Electromyographic recordings were made on a Grass eight-channel oscillograph with bipolar surface electrodes in preference to needle electrodes, whenever possible. Action potentials from various combinations of as many as seven muscles were recorded simultaneously while the reflexes were being elicited and

while the patient was standing, balancing, and walking. Three paraplegics, twenty-two children with cerebral palsy, and six normal children and adults were studied electromyographically. Subcutaneous temperature readings were obtained with a needle thermistor and recorded on a tele-thermometer (model 44 TA).

OBSERVATIONS

Reflexogenous Areas

The size of the skin areas wherein these reflexes may be elicited (Fig. 2) is extensive at birth, but gradually diminishes as the reflex disappears during maturation. The reflexogenous areas are not circumscribed, there being a gradation of sensitivity from the central area to the periphery. If a reflex remains active for several years, which frequently occurs in children with cerebral palsy, there is often an unexplained spread of the reflexogenous area, with the result that it occasionally includes the entire foot. Persistence of extensive reflexogenous areas becomes an ominous sign, suggestive of delayed cortical maturation.

FIG. 2

Typical reflexogenous areas: *a* = toe-grasping reflex; *b* = inversion reflex; *c* = eversion reflex; *d* = dorsiflexion reflex.

Sensory Receptors

It seemed important to determine whether these reflexes were mediated through skin receptors or deep proprioceptive receptors, or both. In the monkey, the toe grasp can be elicited even when the entire plantar skin is anesthetized with novocain [2]. In man, somewhat to the contrary, it has been reported [14] that stimulation of both skin and subcutaneous tissue is necessary to elicit a true instinctive grasp reaction because skin stimulation was considered necessary to initiate the reflex and stimulation of the deep stretch receptors that are necessary to reinforce the strength (holding phase) of the movement. In the present studies it was possible to abolish each of the four tonic reflexes of the foot by local infiltration of procaine into the appropriate reflexogenous areas. The effectiveness of the block was confirmed electromyographically (Fig. 3). Since it is difficult, if not impossible,

to limit the infiltration to the skin alone, the experiments were repeated using ethyl-chloride spray. This was equally effective. To exclude the possibility that the nerve receptors in the subcutaneous tissues were also being cooled by the spray, a needle thermistor was inserted immediately under the skin, with proper insulation of the hilt of the needle, and the skin surface was again sprayed with ethyl chloride. With this technique it was possible to block the reflexogenous area without a measurable drop in the temperature of the subcutaneous tissue. Thus, it seems conclusive that these reflexes are mediated through skin receptors. As observed in palmar grasping [2], if only a portion of the reflexogenous area was anesthetized, the reflex could still be elicited from the non-anesthetized area. Deep tendon reflexes (Rossolimo) could be obtained by tapping of the anesthetized skin.

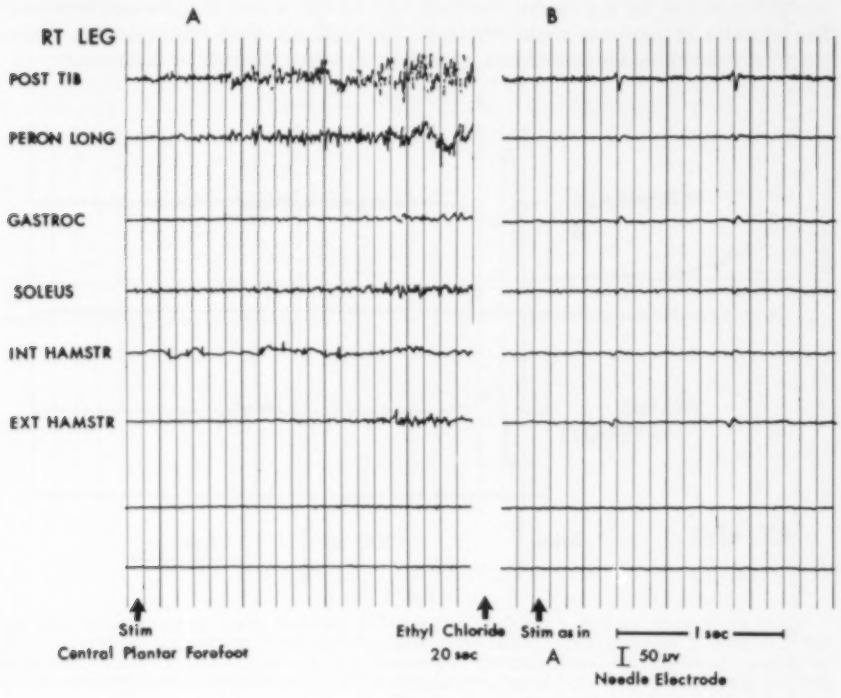

FIG. 3

Electromyographic recordings during elicitation of toe-grasping reflex. Note absence of electrical activity in *B* after blocking of the reflexogenous area with ethyl-chloride spray.

Reflex Arc

It appears certain that tonic reflexes of the foot are spinal reflexes, in that they can be elicited in patients who had surgically demonstrated transection of the upper thoracic spinal cord. Of the eight patients with spinal paraplegia who were studied, three had proved transections of the cord; all eight patients showed reflex activity. The reflexes in these paraplegics were extremely active, forceful movements, occurring through a maximum range after a noticeably shorter latent period than that observed in the other patients studied. The reflexogenous areas were extensive. The level of the reflex arcs could not be established on the basis of information gained from paraplegics because the exact extent of the cord damage was unknown. In one patient with a proved transection at the level of the fourth thoracic vertebra, all four reflexes could be easily elicited. In two other patients with cord lesions at the level of eighth and ninth thoracic vertebrae,

respectively, only the toe-grasp and eversion reflexes could be obtained, and the eversion reflex was less active in the patient with the lesion at the ninth thoracic vertebra. The findings suggest that the reflex arcs are distributed below the level of the fourth thoracic segment. The dermatome distributions of the afferent and efferent pathways are too widely separated to consider these reflexes as simple segmental reflexes.

With the spinal cord intact, the reflex arcs are subject to modification by higher centers. In addition to the suppressive effect just mentioned, it has been shown that the grasp reflex in the monkey [2] and in the human infant [10] can be intensified by postural changes, such as the turning of the patient from side to side. I was unable to modify any of the other three tonic reflexes of the foot by similar positioning. All four reflexes were intensified by the placing of the subject in the upright position, by the startle reaction, and by the waves of increased tension in the muscles of patients with athetosis. The reflexes were unobtainable during sleep and second-stage anesthesia; the toe grasp was the last to disappear.

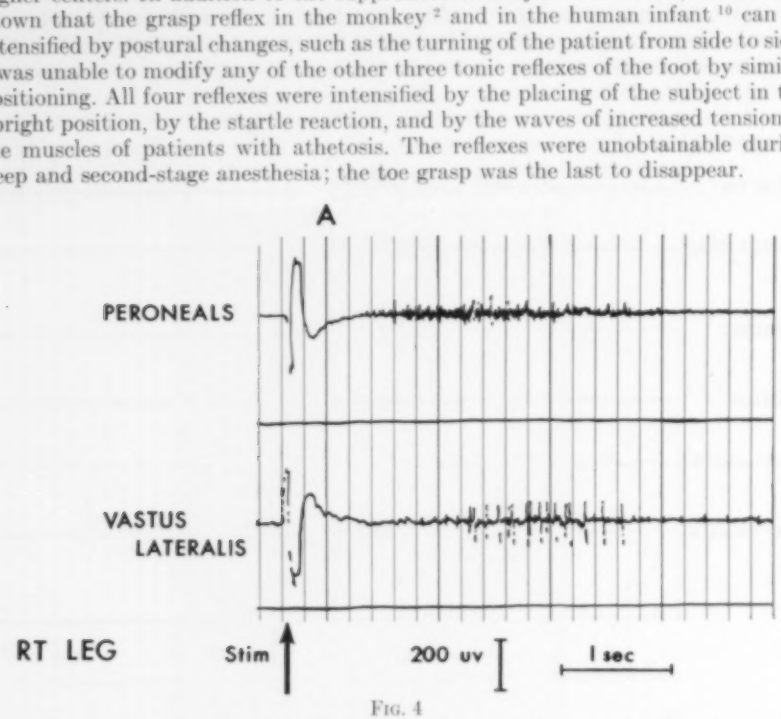

FIG. 4

Electromyographic recording (surface electrodes) of peroneal group and vastus lateralis during elicitation of eversion reflex. Initial deflection is artefact from mechanical application of the stimulator. Latent period (approximately one second) between application of stimulus and initial activity in peroneals. Additional latent period between onset of activity in peroneals (prime mover) and vastus lateralis (co-contractor).

Associated Movement

As each of these four reflexes was elicited, associated activity of a consistent pattern was repeatedly observed, palpated, or electrically recorded in other muscles of the responding extremity. The intensity of this simultaneous muscle contraction appeared to be proportional to the intensity of the reflex movement, being more evident in the young infant or in the patient with cerebral palsy. As the toe grasp was elicited, associated contraction could be observed in the hamstring, gastrocnemius, and soleus muscles. Clonus occasionally developed in the gastrocnemius and soleus muscles.

With the inversion reflex, associated activity occurred in the internal hamstring. The eversion reflex was usually accompanied by contraction of the vastus lateralis and tensor fascia femoris. On elicitation of the dorsiflexion reflex, contraction of the vastus medialis was often observed.

When the timing of this associated movement was studied electromyographically, a latent period of 0.1 to 0.3 second was demonstrated between the onset of

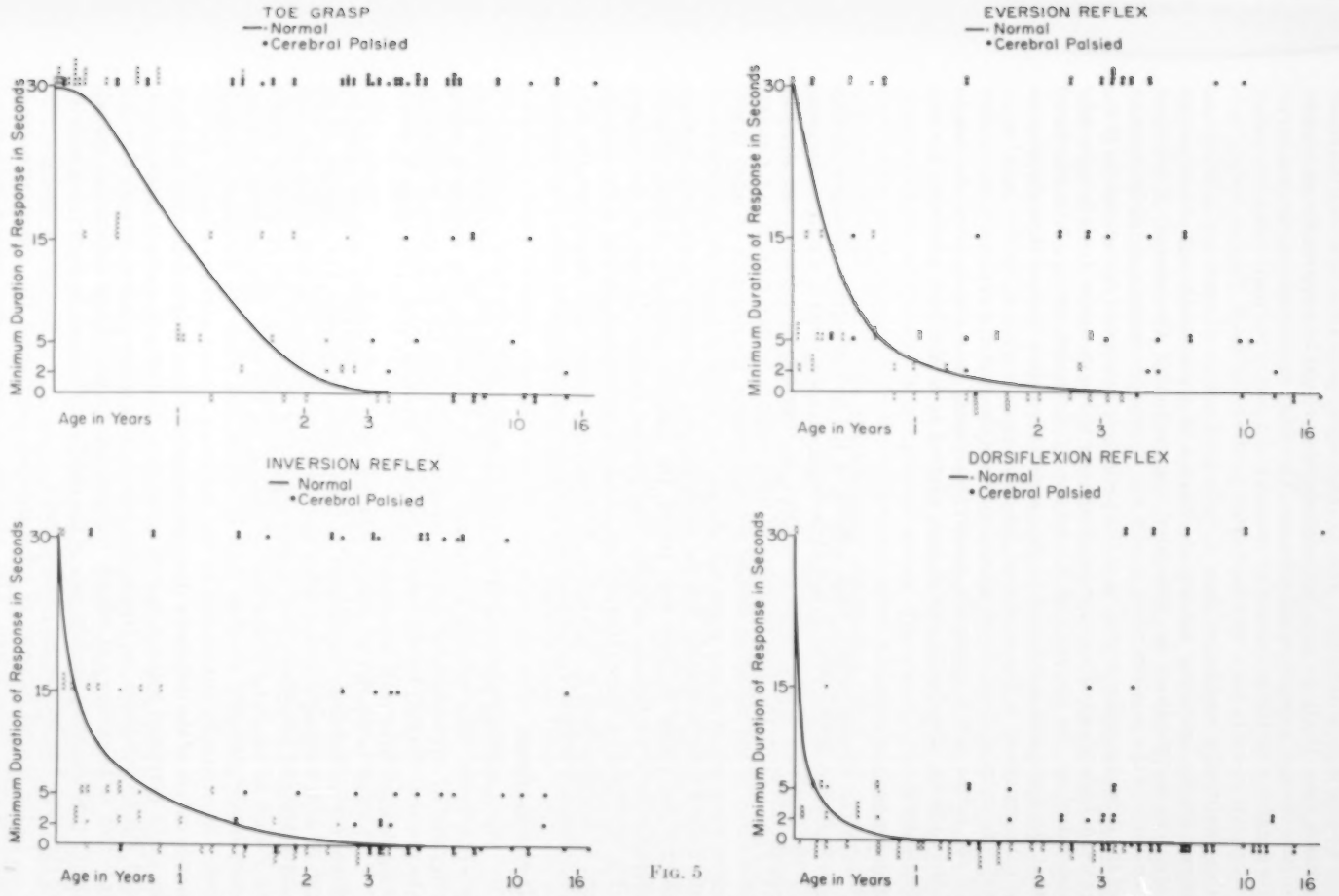

FIG. 5

Disappearance curves (idealized) for each of the four reflexes of the foot plotted from observations in forty normal children (each x represents one foot). Observations in children with cerebral palsy (•) indicate that in many instances the reflexes remain active throughout childhood.

electrical activity in the leg muscles (prime movers) and in the associated muscles (co-contractors) in the thigh (Fig. 4). This latent period far exceeded the transmission time (thirty to forty milliseconds) that would be required for an impulse to pass through a simple spinal reflex arc. This delay in activation of the co-contractor suggests that the associated movement is not part of the basic reflex but rather a separate event in some way dependent on the reflex itself. Further insight into this relationship was gained from a study of the effect of tenotomy of the prime mover on the associated movement. When a strong inversion reflex was present and was accompanied by associated contraction of the internal hamstrings, tenotomy of the posterior tibial muscle was observed to cause a complete cessation of the inversion reflex as well as of the previously associated co-contractors of the internal hamstrings. Thus, associated activity of the co-contractor is in some way dependent on the integrity of the tendon of the prime mover. It seems likely that the associated movement of the proximal muscle is elicited through proprioceptive receptors in the tendon of the distal muscle, so that, as the initial tonic reflex movement slowly develops, activation of the stretch receptors in the tendon of the prime mover gradually recruits increasing co-contraction of the associated muscles. The latent period just referred to is the time necessary for this recruitment.

Disappearance

In the normal infant, tonic reflexes of the foot gradually disappear during the first years of life. Prior to complete disappearance, there is a gradual lessening of the duration of the reflex movement in response to a continuous stimulus (vibrator). Since the disappearance of tonic reflexes seemed related to a suppressive effect of the maturing central nervous system, the duration of reflex movement when tested at any given age should be a useful index of the maturation of the central nervous system. For the establishment of normal values, forty healthy infants and young children were tested; the duration (seconds) of each reflex in response to a continuous stimulus was plotted against the age of the subject (Fig. 5). Based on these observations, idealized curves were plotted of the average age of disappearance of each reflex. Although not statistically significant, the general accuracy of these curves has been borne out by subsequent serial observations.

Deforming Effects

The deforming potential of the tonic reflexes arises out of the dominance of a single reflex, thus causing a dynamic muscle imbalance. The dominant reflex, triggered by environmental stimuli, repeatedly distorts the foot until, eventually, the position dictated by the reflex movement becomes fixed. Two types of dominant reflexes have been encountered:

The first is a reflex of normal intensity that is unopposed because other reflexes are prematurely suppressed as maturation progresses. For example, in an infant with a strong eversion reflex and a weak or absent inversion reflex, the foot will habitually be pulled into a valgus position in response to any general stimulation, such as handling of the foot or tugging on the sock. After several months, such a foot gradually becomes fixed in valgus, but when the dominant eversion reflex is eventually suppressed by the maturing central nervous system, the dynamic nature of the deformity disappears, and the fixed valgus deformity can then be easily corrected without fear of recurrence. Metatarsus varus, talipes valgus, and talipes calcaneus, as frequently seen in the normal infant, presumably fall into this same category of reflexly induced deformities. These deformities are seldom a problem after the first year of the child's life because by then reflex activity of this type has been largely suppressed.

In the second category of reflex-induced deformities, the dominant reflex is pathologically hyperactive. This situation is usually encountered in cerebral palsy. One or more of the reflexes may persist throughout childhood and, instead

of gradually disappearing, the reflex becomes more active as the years pass. At the same time, the reflexogenous area may spread to involve a large area of the foot. Under these circumstances the slightest stimulation evokes a violent movement, and permanent fixation in the deformed position usually occurs.

THERAPEUTIC CONSIDERATIONS

If the serial testing with a standardized stimulus (vibrator) shows no lessening of the duration and intensity of the deforming reflex, it may become desirable to artificially suppress the reflex by interruption of the reflex arc. There are three methods of altering a tonic reflex:

The first is temporary interruption by blocking of the reflexogenous area with ethyl-chloride spray or by infiltration with procaine. Although not practical for continued usage, local anesthesia is a useful diagnostic test to confirm the deforming effect of a reflex. Neurectomy of cutaneous nerves supplying the reflexogenous area, if feasible, affords a more permanent interruption of the reflex arc. This procedure results in a loss of epicritic sensation, but deep sensation adequate to protect the denervated area from trophic damage is retained. The toe grasp has been eliminated by deafferentation in three patients by sectioning of the cutaneous branches of the medial and lateral plantar nerves. The eversion reflex has been abolished in seven patients by section of the sural nerve. All patients, eight spastics and two athetoids, had severe reflex-induced deformities. They are mentioned here only to substantiate the fact that at least two of the reflexes can be interrupted conveniently by deafferentation. The patients have not been followed long enough to determine whether these effects will persist. The practical therapeutic value of the procedure remains to be proved—for the moment, the procedure must be considered entirely experimental.

The second method is counterstimulation of a reflex that is antagonistic to the deforming reflex, which was suggested early in the study. If a patient presented a varus-adduction deformity induced by an active inversion reflex, it seemed logical to methodically stimulate the eversion reflex in an effort to augment the eversion reflex and establish a more equal balance between the two reflexes. This method of treatment was carried out over a period of two years on fifteen selected patients. A vibratory stimulus was used by the parents three times a day for a period of twenty minutes, allowing time for rest when the reflex became fatigued. The results indicated that this procedure has no significant therapeutic value, but they did establish the interesting fact that in a patient with cerebral palsy the duration, ease of elicitation, and strength of a tonic reflex movement can be substantially increased by repeated stimulation over a long period of time.

The third method of altering a tonic reflex is to perform a tenotomy of the prime mover. After tenotomy of the posterior tibial tendon and healing of the elongated tendon, it has been observed repeatedly that there is a prolonged and often permanent disappearance of the inversion reflex. Likewise, tenotomy of the peroneus brevis will alter the eversion reflex. One possible explanation of this result is that during the immediate postoperative period, when the prime mover is temporarily ineffective, the supraspinal center is able to establish suppressive control.

DISCUSSION

The fact that these reflexes reappear in the patient with spinal paraplegia indicates that they have retained their organization even while clinically suppressed when the spinal cord was intact. The question naturally arises whether these reflexes serve any useful function in the normal adult. The grasp reflex has been considered to be a retained primitive prehensile movement by some workers[14] and to be a postural righting reflex by others[7]. Tonic movements are too slow to be useful in prompt righting reactions, but, if, as has been suggested in the case of palmar grasping[14], the tonic reflex movement in reality represents

the summation of a series of instantaneous reflex reactions, then the relation of this tonic movement to function becomes more evident, for the disappearance of the slow tonic movements with maturation could be explained as due to loss of the summating effect. The reflex would continue to function and to initiate contraction of its associated muscles but it would lack the necessary sensitivity to be summated into the slower, purposeless response observed in the newborn.

These reflexes are well arranged to facilitate balancing in stance and gait. If a person standing upright is displaced forward, pressure is produced on the ball of the foot, eliciting a toe grasp and co-contraction of the calf and hamstrings. In a like manner, displacement laterally causes pressure on the lateral aspect of the foot, evoking the eversion reflex and contraction of the peroneals, vastus lateralis, and tensor fascia femoris. Again, with displacement medially, the inversion reflex comes into effect, and with displacement backward the dorsiflexion reflex responds. In each instance displacement evokes the appropriate reflex muscle action to resist the displacement of the body from the upright position. Such an arrangement supports the concept that dynamic posture is a cascaded reflex system that, initiated by appropriate contact of the foot with the floor, proceeds proximally in a chainlike manner. The stretch loading of the tendon of the distal muscle (prime mover) recruits co-contraction of the proximal muscles. The speed and intensity of this chain reaction will, in part, be modified by the force of the initial contact with the floor, together with the degree of stretch loading applied to the distal tendons and, in part, by the inhibitory or facilitory effects of central postural reactions.

SUMMARY

1. Four tonic reflex movements of the foot can be elicited in normal infants and in some older children with cerebral palsy.

2. The disappearance of these tonic reflexes with growth appears related to maturation of the central nervous system.

3. Certain physiological features of these reflex movements are discussed, including the reflexogenous areas, sensory receptors, reflex arcs, associated movement, and disappearance.

4. These reflexes are of orthopaedic interest in that they may, by their occasional unopposed action, cause deformity.

5. It is suggested that these slow tonic movements represent a summation of many instantaneous reflexes, and that these instantaneous reflexes are distally located trigger mechanisms that initiate balancing reactions.

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(Continued on page 874)

The Closed Fracture of the Long Bones*

BY JOHN R. MOORE, M.D., PHILADELPHIA, PENNSYLVANIA

Dear fellow members of The American Orthopaedic Association: First may I take this opportunity to thank you for according me the cherished privilege and the very highest honor of serving as the Seventy-third President of our Association. It is perfectly true that the Secretary and the other officers of the Association carry most of the work load, but you may be assured that there is an inescapably great responsibility imposed upon the President by the rich traditions of this great parent American Orthopaedic Association. This responsibility has not lessened one iota with the growth of the Association's protégé, The American Academy of Orthopaedic Surgeons, that husky youngster now twenty-eight years of age that continues to grow though remaining commendably courteous, respectful, and receptive to parental counsel.

For the past seventy-two years, the Presidential Addresses have probably covered almost every aspect of Orthopaedic Surgery. Strangely enough, there has been no reference to the closed treatment of fractures. One might conclude that its status has never been questioned.

The closed treatment of fractures has been of major interest to the staff of the Department of Orthopaedic Surgery, Temple University School of Medicine, Philadelphia, Pennsylvania, since it assumed the management of fractures and dislocations in 1934. Specialization, though figuratively in its youth at that time, was rapidly becoming synonymous with medical progress, and the training of the orthopaedic surgeon appeared to qualify him best for the proper care of fractures, dislocations, and related trauma. Due to the early teaching of such master orthopaedists as Edward C. Bull of San Francisco, Michael Hoke and Lawson Thornton, both of Atlanta, conservative management became the immediate policy and closed reduction became the by-word of Temple in 1934. The teaching that only the unskilled surgeon resorted to open reduction has been accepted completely by the Staff.

The successful closed reduction of the closed fracture of the long bones has been a thoroughly enjoyable challenge to each and every one in the department. In fact, a successful closed reduction followed by continued conservative management that terminates in successful repair of the fracture is regarded by the staff as a *fait accompli* in the field of traumatic surgery. The senior staff is dedicated to this ideal and will defend its principles with their professional lives. It is their sincere belief that closed fractures of the long bones can be reduced by closed manipulation and carried to successful repair without converting them to open fractures.

In 1943, the writer presented an analysis of 5,189 closed fractures of long bones treated by closed reduction and added to this number an additional 3,560 closed fractures treated in a similar manner in a report read at the Washington Meeting of The American Orthopaedic Association in 1958. Complications in these series were relatively few and open reductions a rarity (less than 5 per cent). Open reduction both then and now has been restricted essentially to non-reducible articular fractures of the proximal portion of the femur and fractures associated with local circulatory failure. Open reduction of fractures during the growth period is limited to the occasional widely displaced radial head, the displaced epicondyle of the humerus, and the widely displaced femoral epiphyseal fracture.

*Presidential Address presented at the Seventy-third Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 1, 1960.

Malunited and non-united fractures in children and adults naturally are not included in the preceding category. The moral is, "Keep the overlying skin and other soft parts intact at the fracture site." Herein lies the principal difference between open and closed reduction. The natural resources at the site of injury remain intact. Name the antibiotic equal to the skin barrier. Is there a better hemostatic agent than the intact skin and the underlying soft parts combined with adequate splinting? Additional injury to the soft parts occasioned by mechanical and surgical trauma is minimized and foreign-body rejection, corrosion of metallic implants, and the plague of infection are totally eliminated. Blood supply of fragments receives less additional damage. The periosteum and blood supply of critical bone fragments remain undisturbed. The risk of needlessly prolonging the hyperemia and acid phase of fracture repair is reduced by the maintenance of an intact skin and adequate splinting. Conversely, the alkaline phase, the appearance of alkaline phosphatase, and the deposition of calcium and phosphorus take place at a relatively earlier period in closed treatment, with a resultant shortened healing period. These advantages attributable to intact skin and adequate splinting combined with restoration of bone contact, adequate immobilization of the joints above and below the fracture, and uninterrupted immobilization until the fracture is healed, prepare the way for the normal histological events essential to osteosynthesis. These may be briefly enumerated as follows: hematoma, granulation tissue, osteoid fiber bone, and, finally, lamellated bone.

THE CONSERVATIVE MANAGEMENT OF THE CLOSED LONG-BONE FRACTURE

Time of Reduction

Immediate reduction is not an emergency.

Immediate splinting of the joint above and below the fracture, physical diagnosis, appropriate treatment of extraskeletal complications, are emergencies. The method of splinting should be optional — the test of adequate splinting is the relief of pain.

Closed Reduction

The time of reduction is dependent upon the following considerations: The swelling at the fracture site must be minimal in order to minimize the obstruction to reduction offered by hydraulic pressure. The reduction, therefore, may be immediate or delayed.

The patient must be capable of taking, with minimal risk, an anesthetic which affords complete muscle relaxation.

The reduction must be done by a skilled surgeon or under the guidance of a skilled surgeon who is familiar with the simple mechanical principles.

The procedure for reduction must be planned and there must be adequate assistance and materials.

Planning the Reduction

The deformity must be analyzed from adequate radiographs. The principal pitfall lies in the failure to recognize or evaluate the rotational component of the deformity. The components of the deformity should be identified and a description of the deformity written down indicating preferably the position of the distal fragment with reference to the proximal fragment in terms of displacement, angulation, rotation, and distraction or over-riding.

The Reduction

This consists essentially in neutralizing or reversing the elements of the deformity previously outlined. This is accomplished by traction and countertraction on the opposing fragments. The most common pitfalls leading to the difficulty in the reduction are failure to recognize or evaluate rotation and failure

to apply countertraction. Countertraction is often inadequate and poorly directed. Traction if unsuccessful is usually either inadequate or excessive. Failure to apply traction in the line of the deformity is the next most important cause of failure, and last, but by no means least, is the error of attempting to reduce only one of the elements of the deformity rather than reducing all together in what might be called a symphony of movement. The simple rule for closed reduction is to apply adequate traction in line of deformity and then engage the fragments.

Immobilization

The stability of the fracture must be evaluated. For teaching purposes, fractures may be classified in many ways, according to whether they are open or closed, according to the force mechanism producing the fracture, according to occupation, and so forth. However, the classification as to stability is probably most important. Stability can be determined only after closed reduction has been attempted. Unfortunately, this fact is not accepted or not recognized and assumed instability serves as one of the principal excuses for open reduction. Some of the unstable group of fractures can be taken care of simply by applying carefully a non-padded plaster cylinder splint with adequate assistance. In other unstable fractures the application of a carefully molded plaster cylinder may be supplemented by cutting two small circular windows over both the upper and the lower fracture fragments and inserting half pins, preferably into cortical bone well away (two to three inches) from the fracture site and two inches apart. After being inserted the pins are incorporated in the plaster and a cylindrical section of the cast is removed over the fracture site. Reduction is then repeated and when it is satisfactory the two sections of the cast are reattached to each other with plaster. These pins are stainless steel and two millimeters in diameter; they pass through the skin, proximal cortex, and medullary cavity and project through the opposite cortex three to four millimeters. They are called half pins because they do not traverse the opposite soft parts. They may be removed or reinserted at different levels if they produce irritation. These small half pins and the plaster cylinder can readily be applied to the proximal and distal fragments in difficult reductions, permitting precise manipulation of fragments. The pins may be left in or removed depending upon the stability of the fracture after reduction. The use of these half pins has for the author solved the problem of the unstable fracture.

Duration of Immobilization

Immobilization must be continued uninterrupted until the fracture is healed. The surgeon must be familiar with the time schedule for young and old. He must also be familiar with the radiographic signs of union, slow union, delayed union, and non-union; he must know how to interpret these signs intelligently.

Permanent arthrofibrosis is inexcusable. Joints that are immobilized in positions of physiological rest without strain, that are not injured at the time of accident, that are protected against edema due to constriction by the cast or to dependency, and that are not subjected to traction or compression, do not become ankylosed.

Muscle atrophy is reversible. Muscles unless injured by the force producing the fracture, by edema due to dependency, or by needlessly prolonged immobilization, do not develop permanent myostatic contractures.

The foregoing principles of conservative management of the closed fracture and the fundamentals of fracture healing have been the basis for the management of the two series of fractures previously reported by the writer in 1943 and 1958, and it will serve as a base line for the discussion to follow. Dogmatism in this discussion is quite noticeable, but this is based upon good solid conviction supported by experience.

This very satisfactory concept of the closed fracture and its treatment, a

concept that has been supported by the continued scientific advancement in fracture healing, particularly in the basic sciences, was rudely shattered by the sudden realization that the trend, since World War II, has been decidedly toward open reduction. Originally, open reduction was employed only in so-called, "specially selected cases", but it has gained momentum with the broadening of this classification. The slow but steady stream of tragedies secondary to the open reduction of closed fractures of the long bones that has come into the Orthopaedic Clinic at Temple University Medical Center during the past four years has awakened the staff to the change in methods of treatment that has occurred. Fifty ununited fractures of the long bones, complicated by osteomyelitis following open reduction, were reviewed in preparation for this presentation. Six of these cases are briefly reported:

CASE 1. Ship's engineer, forty-two years old. Closed, long oblique fracture of the mid-shaft of the left humerus. Closed reduction was unsuccessful due to failure to obtain contact of the bone ends and to inadequate immobilization. An open reduction and internal fixation with a plate and four screws was complicated by a wound infection. Immobilization was continued for four weeks. Non-union ensued. The following procedures were then carried out: in 1954 open reduction and bone graft followed by non-union; in 1955 open reduction and internal fixation with a Küntscher nail followed by non-union; in 1956 open reduction with fixation with a Küntscher nail and a bone graft followed by non-union; in 1958 a bone graft followed by four and a half months in a shoulder spica and union. The over-all result in this case was union of the fracture, a patient who had been out of work for five years, medical expenses of about $10,000, only part of which was covered by insurance, and the patient's family requiring support from relatives.

CASE 2. A boy, eighteen years of age. Closed fracture of the mid-shaft of the right femur. An inadequate closed reduction, followed by inadequate immobilization, led to an open reduction and fixation with a Küntscher nail. This procedure was complicated first by infection and osteomyelitis and then by fracture of the femoral neck and the development of suppurative arthritis of the hip joint secondary to the insertion of a nail through the region of the trochanter. The total end result in this case was union of the fracture but four inches of shortening of the leg, a draining sinus, a stiff knee and stiff hip, medical expenses estimated at $7000, interruption of the patient's education for two and a half years, and a patient who is a cripple needing a built-up shoe and a cane.

CASE 3. A girl, eleven years of age. Closed fracture of both bones of the left forearm. An open reduction and internal fixation with a plate and four screws for each bone was unsuccessful. The result to date is non-union with a low-grade infection of three years' duration, medical expenses only partly covered by insurance, disrupted home life and school life, and moderate psychiatric problems.

CASE 4. A woman, fifty-three years of age, the wife of a laborer and mother of five children. Closed fracture of right tibia. A closed reduction was unsuccessful. An open reduction failed and was followed by five operations in the ensuing four years and an amputation leaving a short below-the-knee stump. The over-all end result in this case was amputation, indebtedness of $4500 (there was no insurance), her family supported by city and county welfare agencies, and her husband disabled by a heart attack attributed to the stress of his economic and physical load.

CASE 5. A housewife, thirty-one years of age. Closed fracture of the right tibia. A closed reduction was attempted unsuccessfully. An open reduction was followed by six operations and a below-the-knee amputation four and a half years after injury. Surgeon's comment: "I guess I should not have opened it."

CASE 6. An artist, fifty-four years of age. A closed fracture of the left tibia and fibula at the junction of the middle and lower thirds. A closed reduction was attempted unsuccessfully. An open reduction with intramedullary fixation resulted in osteomyelitis and non-union. The total result to date is non-union, continuous drainage, hospital and medical expenses exceeding $5000, need for crutches and a long leg brace, and interruption of his work for three years, not to mention his wife's two coronary thromboses.

The over-all picture for the whole group of fifty non-unions was essentially the same. Closed reduction had been attempted in a relatively small percentage and even in these it is questionable if the attempt at reduction was an honest one. One or more open reductions invariably followed the unsuccessful closed reduction and these were all complicated by non-union, or non-union and osteo-

myelitis. With few exceptions these fractures were in adults in the wage-earning group. Non-unions not complicated by infection offered great difficulty in surgical repair because of the loss of bone substance. In non-unions complicated by osteomyelitis, the problems were insurmountable. In many the apparatus used for internal fixation was still present even after two or more years. Cleaning up these fractures invariably left large bone defects, continued infection, and, in almost all cases, poor skin coverage. Amputation was the patient's choice in many instances. The work loss in this group averaged more than two and a half years. The average loss of income was estimated at more than $8000. The hospital costs ranged from approximately $500 to $7000, even though these costs were partially covered by insurance. Many homes were disrupted because of what appeared to be an impossible financial load or because of the stress on other members of the family, stress which not infrequently terminated in tragedy. These were fatalities due to coronary thrombosis, both attributed to stress occasioned by the fractures and their complications. Looking into the home life of these patients was an experience one cannot appreciate except through personal contact. The worn, desperate, frustrated patient, appearing in the Clinic, with a draining sinus, in a wheel chair or on crutches, portrays only a very small part of the real tragedy associated with this problem.

A recent paper, yet to be published, covered a study of 741 ununited fractures of the long bones upon which 910 operations had been performed in an attempt to obtain union. The author listed open reduction complicated by infection as the principal cause of non-union. There were thirty-one complete failures in this group with eleven amputations.

A European author recently reported 160 cases of intramedullary fixation of long bones complicated by non-union; thirty-three of these were non-unions associated with osteomyelitis.

These failures are shocking, yet they need not deter progress if the causes of failure can be constructively analyzed and eliminated. Can one say that these open reductions were not properly conceived or properly executed? The resistant staphylococcus and streptococcus, according to all reports, show no partiality to host or surgeon.

In the group of cases collected and studied by the writer, there were certain basic findings prevalent in almost every instance. The surgeons' attitudes toward their failures were invariably casual. This attitude was best illustrated by one surgeon, who after five attempts at open reduction on a housewife with several children, terminated the problem from his point of view with amputation and the remark, "I guess I should not have opened it."

The blame for failures usually falls in one of the following categories:

1. The patient was not cooperative.
2. The metals were defective.
3. The wound healing was complicated by the persistence of a resistant organism.

The surgeon in many instances was convinced that closed reduction would have failed and that open reduction was the patient's one and only chance. Often the surgeon excused himself of the responsibility by stating that the patient insisted upon open reduction because it meant earlier and better recovery.

In no instance in our series did the original surgeon call to inquire as to the patient's progress once the patient had left his care. Not all of the original x-rays were available, but from those available and from the descriptions offered by the original surgeon, there was not a single instance in my opinion in which closed reduction could not have been carried out and conservative management employed. In the cases in which closed reduction had been tried, it was obviously performed without confidence, and I must say without skill, and perhaps even more important, without interest.

I do not know the answer to the trend and the complications. Obviously, if

open reduction is to be continued, these catastrophes must be eliminated. Closed reduction should be revived, studied, and improved. The surgeon and the young trainee should be acquainted with the closed fracture of the long bones and its natural resources. Every closed fracture of the long bone should be given an honest trial at closed reduction. This step should be a prerequisite of every open reduction of a fracture of a long bone. Internal fixation should be only considered for unstable fractures and then only if conservative methods of external fixation have proved ineffective. A higher award should be offered for the successfully managed closed fracture than for the fracture treated by open reduction.

In closing may I make this appeal — Keep the closed fracture closed.

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Tonic Reflexes of the Foot

(Continued from page 868)

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Proceedings

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Twenty-seventh Annual Meeting of The American Academy of Orthopaedic Surgeons was held at the Palmer House, Chicago, Illinois, January 23 through 28, 1960, under the Presidency of Dr. Harold A. Sofield.

At the Second Executive Session, the new President, Dr. Hugh Smith, Memphis, Tennessee, was inducted into office. The following officers were elected:

President-Elect: J. Vernon Luck, M.D., Los Angeles, California;
Vice-President: George J. Garceau, M.D., Indianapolis, Indiana;
Treasurer: Carroll B. Larson, M.D., Iowa City, Iowa;
Secretary: Clinton L. Compere, M.D., Chicago, Illinois;
Librarian-Historian: Edward T. Smith, M.D., Houston, Texas.
Executive Committee:
Robert Lee Patterson, Jr., M.D., New York, N. Y.;
H. Relton McCarroll, M.D., St. Louis, Missouri;
Harold A. Sofield, M.D., Chicago, Illinois.
Junior Members of the Executive Committee:
James S. Miles, M.D., Denver, Colorado;
Edward D. Henderson, M.D., Rochester, Minnesota.
Chairman of the Membership Committee: Carter R. Rowe, M.D., Boston, Massachusetts.
Chairman of the Committee on Scientific Investigation: Robert D. Ray, M.D., Chicago, Illinois.
Chairman of the Committee on Public Relations: William J. Tobin, M.D., Washington, D. C.
Chairman of the Nominating Committee: Don H. O'Donoghue, M.D., Oklahoma City, Oklahoma.
Chairman of the Committee on Instructional Courses: Fred C. Reynolds, M.D., St. Louis, Missouri.
Chairman of the Committee on Audio-Visual Education: Garrett Pipkin, M.D., Kansas City, Missouri.

Dr. David S. Grice, Philadelphia, Pennsylvania, was appointed Chairman of the Program Committee.

The next Annual Meeting of The American Academy of Orthopaedic Surgeons will be held in Bal Harbour, Miami Beach, Florida, January 8 through 13, 1961.

Summaries of the papers presented at the Scientific Session follow:

Combined Program of the Orthopaedic Research Society and The American Academy of Orthopaedic Surgeons

The Cytodifferentiation of Osteoblasts in Tissue Culture. A Description of Cellular Emigrations from Embryo Chick-Leg Bones. Dr. George G. Rose [1] and Dr. Thomas O. Shindler [2]. (J. Bone and Joint Surg., **42-A**: 485-498, Apr. 1960.)

An Investigation of the Engineering Design of Hip Nails and the Development of the H-beam Nail. Dr. Patrick G. Laing [3] and Mr. John M. O'Donnell [4] presented the report of a cooperative project between orthopaedic surgeon and engineer to determine the best engineering design for hip nails, considered only from the point of view of fatigue resistance. Test specimens of the trifin, I-beam, and H-beam shapes were manufactured from A.I.S.I. 316 stainless steel to fit the R. R. Moore rotating beam fatigue-testing machine. Stress analysis of these cross sections revealed the H-beam to be the strongest of the three; at over 10 million cycles, the trifin cross section could withstand a loading of fifty-one pounds; the I-beam, fifty-eight pounds; and the H-beam could not be fractured at ninety-one pounds. Smaller H-beams were found to be very much stronger than the trifin or I-beam designs. H-beam nails made of cast Vitallium on direct transverse bend testing have a yield strength between two and three times that of a cast Vitallium trifin or four-flanged nail.

The H-beam nails have been used in the treatment of fractured femoral necks, both intracapsular and extracapsular, and in arthrodeses of the hip, but the results have not yet been determined.

The Vasculature of the Bones of the Extremities of Man. Capt. John G. Nork [5], Dr.

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James B. Wray [6], Dr. William B. Jones [7], and Joseph E. Markee, Ph.D.[8], presented a study of the total vasculature of human bones obtained from freshly amputated specimens. The thirteen limbs used in this study were selected from a total of sixty on the basis of absence of peripheral vascular abnormalities and the excellence of the final preparation. Immediately after amputation the total vascular bed of the extremity was flushed clean with normal saline solution. Twelve to twenty-four hours later methyl methacrylate was injected into the major arteries, producing a model of the total vascular bed. Specimens for study were then prepared in three ways: (1) Sections of unfixed and undecalcified bone, thirty micra in thickness, were cut with the Gillings-Hamco thin-sectioning machine. Preparations so produced permitted visualization of injected vessels in direct relationship to the surrounding bone; (2) Other bones were treated with 5 per cent potassium hydroxide solution, removing all soft tissue and permitting demonstration of the periosteal circulation and immediately underlying bone; and (3) Bones previously treated with potassium hydroxide solution were then immersed in 10 per cent hydrochloric acid solution. After several days all material other than previously injected plastic was removed. Careful observations were made on all three types of specimens and were recorded with microphotography.

Extensive study of these specimens led to several general conclusions: (1) The arterial supply of bone is derived from nutrient, periosteal, metaphyseal, and epiphyseal arteries which interconnect, both intra-osseously and extra-osseously; (2) The major venous drainage of bone occurs by two routes: the numerous, but small, subcortical sinusoids of the diaphysis draining into the periosteal veins and the multiple metaphyseal sinusoids draining into metaphyseal veins; and (3) The arterial and venous systems of bone are strikingly independent of one another—of many thousands of Haversian vessels observed, all were felt to be single.

In discussion, Dr. Jonathan Cohen [9] pointed out that since the plastic injection mass does not fill vessels with a diameter of seven micra or less, the channels by which the injected material reaches the veins may be through vascular shunts rather than through the principal microcirculation of bone (which serves as its ultimate nutritional transportation system). He also noted that the means of differentiation between arteries and veins may not be entirely accurate, and that the blood flow within Haversian systems is still completely unknown in respect to its direction and volume. He felt that a combination of the authors' excellent injection technique and other techniques may well further elucidate the important subject of the microcirculation of bone.

A Longitudinal Study of Digital Fusion in Adolescence. Dr. Leroy S. Lavine [10], Melvin L. Moss, Ph.D., and Charles R. Noback, Ph.D., reported on the first longitudinal roentgenographic study of the process of epiphyseal fusion in man. Using closely spaced serial roentgenograms of fifty-four children, the authors studied digital epiphyseal fusion of the adolescent hand.

A unit scoring method for quantitating epiphyseal maturation allows direct comparison between children without regard to age, sex, or pattern of maturation. This method is easily adapted to routine clinical practice.

The average elapsed time for fusion of fifteen digital epiphyses of the hand was approximately sixteen months, with a range of from four to twenty-eight months.

The rate of digital epiphyseal fusion of a child is not correlated with sex, digital length, chronological age, or the number of epiphyses undergoing maturation. Apparently, the correlating factor is the length of time required to complete the fusion process in any given epiphysis.

Because maturation of the hand is accepted as the best indicator of total skeletal maturation, this method gives the clinician a simple reliable system for determining bone age.

The Use and Distribution of Radioactive Sulphur in Patients Having Chondrosarcoma. Dr. Raymond G. Gottschalk [11] carried out an investigation to determine whether the selective uptake of radioactive sulphur by cartilage and the active formation of cartilage by chondrosarcomata would make radiosulphur an effective therapeutic agent in advanced chondrosarcoma. Tracer amounts of S^{35}-sulphate (1.8 to 6.7 millicuries) were injected intravenously into five patients with chondrosarcomata and one with pleomorphic sarcoma. Analyses of the biopsied tissues showed that normal cartilage and chondrosarcomata retained large amounts of S^{35} for long periods of time. The average S^{35} concentrations in the chondrosarcomata varied from 62 to 440 per cent of those in cartilage. Radioautographs showed that S^{35} was fixed mainly near metabolically active chondrosarcoma cells. A high uptake was also demonstrated in chondromata, and in repairing connective tissue, surgical wounds, and fracture. The red bone marrow initially fixed large amounts of isotope, but did not retain it as long as the cartilaginous tissues.

Other experiments have shown that administration of large amounts of radioactive sulphur to experimental animals produces a selective and permanent necrosis of the proliferating cartilage of the epiphyseal plates and a temporary depression of the bone marrow.

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On the basis of these studies, three patients having unresectable chondrosarcomata received large amounts of S^{35}-sodium sulphate (559 to 926 millicuries) in divided intravenous injections. Biopsies were obtained after tracer and therapeutic doses to determine the isotope concentrations in the tissues. Because of the high uptake and long retention in the chondrosarcomata, the isotope delivered cumulative irradiation doses above 4,000 rad to the growing portions of the tumors, whereas the normal tissues studied received much lower doses. Moderate to severe leukopenia and thrombocytopenia developed in each patient, and this limited the amounts of isotope that could be administered. In two patients the clinical observations suggested that the growth of the tumors was arrested or markedly retarded for several months after the isotope injections, although there was no tumor regression and the tumor growth was resumed at a later date. It was emphasized that further clinical trials were needed and that such therapeutic attempts must be limited to patients having a fatal prognosis by the usual therapeutic methods.

Nylon Grafts in Tendon Defects: An Experimental Study. Dr. Edwin David Weinberg [12] reported investigations in which experimental defects in tendons were filled with a nylon woven mesh sutured to the ends of severed tendons in the forelegs of twenty dogs. The nylon inserts were examined grossly and histologically at intervals up to eight weeks after placement. The tendon was observed to regenerate through the nylon with no foreign-body or giant-cell reaction seen. By eight weeks, only an occasional nylon strand was visible in the collagenous tissue of the regenerated tendon.

Sunday, January 24

Polymer Osteosynthesis. Dr. Irving Redler [13], Dr. G. Gernon Brown, Jr.[14], and Dr. William V. Trekell [15] reported their experience with the use of the polyurethane polymer, ostamer, in fifty-one operations performed on forty-two patients. The procedures included internal fixation of acute and pathological fractures, treatment of fractures with delayed union and nonunion, arthrodeses, osteotomies, and the filling-in of one bone defect.

Treatment of Bone Lesions with Ostamer. Dr. Michael P. Mandarino [16], Dr. Joseph E. Salvatore [17], and Dr. Thomas L. Jones [18] reported the results of sixty operations performed since October 1956, in which the polyurethane polymer, ostamer, had been used for the internal fixation of fractures, for fusions of the spine, for filling-in of bone defects, and for the arthrodesis of joints. The results were rated as successful in fifty-five of the sixty patients, many of whom had previously had multiple operations, as well as infections. Included in this report were twenty-two procedures on the tibia, fourteen on the lumbosacral spine, twelve on the femur, four on the humerus, three on the hip, and one each on the ulna, knee, and elbow.

An Ostamer Study in Rabbits Leading to Its Use or Misuse in Humans. Dr. Frederick R. Thompson [19] and Dr. M. Ziya Sezgin [20] reported on the effect of ostamer on the healing of experimental fractures of the tibia in rabbits. All fractures were immobilized by intramedullary Kirschner wires, but various experimental conditions were employed involving different treatments of the periosteum and different locations of the ostamer relative to the bone ends. When the periosteum was left intact and the ostamer was placed only in the intramedullary space through a window in the cortex, the fractures united in eight weeks; however, twelve weeks after implantation (the duration of the experiment) the ostamer showed no evidence of being replaced by bone. When the periosteum was elevated from the tibia and the ostamer placed all around the bone subperiosteally and between the bone ends, as well as in the intramedullary canal, healing did not occur by the twelfth week. When the periosteum near the fracture site was completely excised and the ostamer similarly placed all around the bone ends no healing had occurred by twelve weeks. Histological studies failed to reveal any evidence that bone invaded the ostamer, and a considerable degree of inflammatory reaction around the ostamer was observed. Infections developed in a large percentage of the rabbits in which ostamer was used.

Ostamer was found to bond to dry but not to moist bone. When the surfaces were moist relative fixation was achieved only by the plastic molding about the irregular contours of the bones. The use of screws as binding posts for the ostamer proved unsatisfactory since the screws eventually pulled loose.

Additional findings were: that ostamer is not permeable to carbon dioxide or to a water-

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soluble dye; that it tends to soften after being in the tissues or after exposure to ethyl alcohol; and that *in vitro* some shrinkage occurs as the plastic sets. The authors also observed that the temperature, as well as the speed and duration of mixing, used for the preparation of the plastic influenced its behavior during setting and its ultimate strength in ways not previously reported. It was the authors' opinion that only in very rare instances would there be a situation where ostamer in its present stage of development would be preferable to standard methods of treatment in current use.

In the discussion that followed the three papers on ostamer, Dr. Tom Outland [21] pointed out the need for a longer and more detailed follow-up evaluation of Dr. Mandarino and associates' cases. In evaluating these results Dr. Outland stressed the necessity of differentiating between clinical stability of the fracture due to the plastic bond and unequivocal stability resulting from bone union—the ultimate aim of all fracture treatment. With regard to Dr. Thompson and Dr. Sezgin's paper, Dr. Outland noted what he considered to be certain technical defects in the experimental procedure employed and expressed the opinion that the results of these experiments could not be related to those of Dr. Mandarino. In connection with the paper presented by Dr. Redler and associates, Dr. Outland noted the high incidence of complication and expressed some doubt as to the soundness of the indications selected for the use of this material in the series reported.

Dr. Julius S. Neviaser [22] noted that two complications—drainage and failure of fixation—have followed the use of ostamer. Based on a personal experience with thirty cases, he expressed the opinion that the drainage was probably caused by the abrasive qualities of the surface of the ostamer, rather than by a foreign-body reaction. He attributed the technical errors to failure of the ostamer to hold the bone fragments and stated that he had used a polyethylene-covered metal form placed about the bone and setting plastic to ensure the formation of a dense and firmly fitting plastic mass. He concluded his remarks by stating that currently he was using ostamer—with but rare exceptions—only for pathological fractures secondary to malignant disease.

Dr. Charles Rombold [23] reported experiments on eleven dogs in which ostamer was used to form a splint approximately three-quarters of an inch in diameter that encased and immobilized the spinous processes after spine fusion. In ten of the eleven dogs the wounds broke down three to four weeks after operation. Although various organisms were cultured from the wounds it was Dr. Rombold's opinion that the drainage resulted from a tissue reaction to the ostamer. At the time of sacrifice the ostamer was found to be contained within an abscess that was walled off by scar tissue. The soft tissues surrounding the abscess showed, on microscopic examination, an inflammatory and foreign-body reaction, but the fusion area was not so involved. In the one dog without drainage from the wound there was no inflammatory reaction, but the ostamer was not adherent to the spinous processes embedded in the plastic and there was no evidence of invasion of the ostamer by bone. Dr. Rombold concluded that ostamer was not ready for general use.

Dr. Bernard Bloch [24], a pioneer in the field of chemical osteosynthesis, commented briefly on the use of plastics in orthopaedic surgery. He noted that in contrast to the epoxy resin adhesive he had used, ostamer is a foaming isocyanate and that it is more of a bulk filler than a true adhesive. He stressed several points: (1) that none of the plastics used to date in orthopaedic surgery had been developed specifically for the purpose; (2) that the ideal resin in still to be found; and (3) that in his opinion the ideal substance should be inert, it should set with no exothermic reaction and have no cytotoxic effects, it should be porous to allow callus to grow throughout, it should be sufficiently strong and have sufficient bonding strength to bone to withstand service conditions in the body, its method of application should be simple, and it should be easily removed, if necessary. In addition to experiments on animals, Dr. Bloch reported that he had used his techniques—in which the epoxy resin, re-enforced with volanized fiber cloth impregnated with the resin is wrapped around the fracture site—in twenty-one patients with fractures in both the upper and the lower extremities. In 25 per cent the results were successful. He stated that he had discontinued the use of plastics in human beings, pending further research, and expressed the opinion that no plastic should be used without a full understanding of its technology, and only if the full chemical formula of the substance is known. He emphasized the need for further research and expressed the opinion that neither ostamer nor the epoxy resin should be used except for selected cases—pathological fractures or unusual situations where standard methods had failed.

Dr. Walter Hoyt, Jr.[25], discussed the physical properties of polyurethane foam, pointing out: (1) that its tensile strength varies greatly according to the method of mixing; (2) that the exothermic reaction at mixing temperatures of 80 degrees Fahrenheit may produce temperatures as high as 160 degrees Fahrenheit; (3) that the plastic's adhesive strength to bone is less than 100 pounds per square inch; (4) that its strength is such that it must be increased with metal re-enforcements; and (5) that its cellular spaces do not communicate with one another. He concluded that ostamer and other plastics should be further investigated before they are widely accepted and used.

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Bone Grafts to the Long Bones. A Follow-up Report after Thirteen Years; a Report of 188 Bone-Graft Operations. Dr. William A. Bishop, Jr.[26], and Dr. Alvin L. Swenson [27] used cortical or cancellous bone grafts in the treatment of 181 ununited fractures (151 patients). In addition, in all but twenty-five procedures some type of internal fixation was included, with intramedullary nails or slotted plates predominating.

Follow-up of the cases—which varied in the types of grafts used and in the techniques of immobilization and treatment of the fracture—showed twenty-six failures recorded, thirteen of which succeeded after a second operation. In the series twelve infections occurred, eight of which were recurrences of an initial infection. Two fractures in this group failed to unite, and the limbs had to be amputated. In the successful cases, the healing time was twenty-one weeks for cancellous grafts and 24.5 weeks for cortical grafts.

The number of failures with cortical grafts exceeded the other types of grafts significantly. The authors, therefore, recommended cancellous-bone grafts for non-union of fracture, with appropriate skeletal fixation and individualized treatment of the non-union.

Monday, January 25

Bone Cysts: Results of Surgical Treatment in Two Hundred Cases. Lt. Comdr. M. C. Wilber [28] and Capt. G. W. Hyatt [29] evaluated 200 bone cysts, reports of which were taken from the files of the Navy's Tissue Graft Registry. The only common factor in the surgical treatment of these 200 bone cysts was the use of freeze-dried bone homografts, provided by the Tissue Bank of the Naval Medical School. Sixty-nine per cent of the cysts were found in patients under the age of fifteen. The bones most frequently involved were the humerus, femur, and tibia. The results in 50 per cent of the cases were classified as failures. The first postoperative roentgenogram usually manifested these failures. The authors were of the opinion that such early evidence of recurrence represented inadequate surgical excision of the cyst. Adequate excision of the lesions is of primary importance; of secondary importance is the type of bone graft used to fill the excised cyst.

The Orthopaedist and Apical Lung Carcinoma. Dr. Paul E. Dee [30], Dr. R. Glenn Smith [31], Dr. Miles J. Gullickson [32], and Dr. Charles S. Ballinger [33]. (J. Bone and Joint Surg., **42-A**: 605–608, June 1960.)

Injuries to the Proximal End of the Radius in Children. Dr. Paul I. O'Brien [34] presented an analysis of ninety-five fractures of the neck and the proximal epiphysis of the radius in children under sixteen years of age treated at the Boston City Hospital from 1948 to 1958. Eighty-two fractures were treated conservatively. In eleven, treatment consisted in open reduction of the epiphysis; in one, partial resection of the radial head; and in another, total resection of the radial head. In addition, twenty-four patients who were operated on from 1934 to 1948 were reviewed.

The author stated that there seem to be two principal mechanisms of injury: (1) forced valgus of the elbow with the forearm pronated causes compression and fracture in the neck of the radius, and (2) posterior dislocation of the elbow causes anterior displacement of the proximal radius from impact of the radial head with the external condylar epiphysis. The injuries were divided into three types: (1) angulation of the epiphysis to 30 degrees, (2) angulation from 30 to 60 degrees, and (3) angulation from 60 to 90 degrees. There were four cases of uncommon, true slipping of the proximal epiphysis without fracture.

The results in the majority of fractures of the first type were excellent, except for occasional early closure of the epiphyseal line with mild secondary cubitus valgus. Similar results were seen in many fractures of the second and third type. Poorest results were seen in the patients who required surgery. Of the fractures associated with dislocation of the elbow, radio-ulnar synostosis developed in six. Large radial heads and notches in the radial necks developed in several patients. The notching of the neck was felt to be due to constriction of the annular ligament. Other changes seen were avulsion of the medial epicondyle, damaged external condylar epiphysis, and forearm shortening.

The author's conclusions were: (1) conservative treatment should be given when angulation is less than 30 degrees, (2) manual reduction with anesthesia should be used when there is angulation from 30 to 60 degrees, (3) gentle open reduction should be used when manual reduction fails or if there is more than 60 degrees of angulation, (4) delayed open reduction should be avoided, (5) the growing epiphysis should never be excised, and (6) displacement with elbow dislocation indicates a poor prognosis.

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34. 1101 Beacon Street, Brookline 46, Massachusetts.

Internal Fixation of Fractures with Flexible Wire and Pins. Dr. Frederic W. Rhinelander [35] discussed internal fixation of fractures by flexible steel wire and small-diameter steel pins and illustrated by roentgenograms the excellent results obtained by proper application of the method. The author pointed out that since new-bone formation and resorption both take place at the fracture site, rigid internal fixation of fractures is neither necessary nor appropriate, and that wire and pin fixation, often supplemented by plaster support, met the requirements of bone repair very well. A cast, when used, could be removed for early mobilization.

The importance of correct surgical technique was stressed. Wires must be properly placed and sufficiently strong (18-gauge for femur and tibia and 20-gauge for humerus, radius, ulna, and fibula), and a sufficient number must be used. Wires must not be overstrained when they are tightened, and the periosteum should not be stripped for passage of wires around bone. Small pins (segments of Kirschner wire) should be employed freely for fixation of fragments near joints. Special bone-holding instruments—a C-clamp with drill guide, a wire-tightening bone clamp, and a wire tightener and twister—allow for great technical facility with a minimum of exposure. For permanent internal fixation, the author demonstrated a wire washer set (which acts like a bolt with washers and nuts); a sliding L-plate (shaped like an angle iron, with one flange seated in a longitudinal saw cut to control rotation of transverse shaft fractures, without holding bone fragments apart); and a key-type of bone graft (secured by wires passed through drill holes) for non-union due to rotation around intramedullary rods.

Laboratory tests and clinical experience showed that electrolytic reaction is not a problem. Wire loops did not cause erosion of bone, any more than screws, unless the bone moved as a result of inadequate fixation, nor did they produce zones of cortical necrosis. Wire loops did not inhibit periosteal new-bone formation, if, by avoiding periosteal stripping, the potential for new-bone formation was preserved.

Internal fixation of fractures should follow the best principles of surgery, with the least possible disturbance of tissue. Dr. Rhinelander believes that his method of internal fixation, which depends primarily on flexible wire and pins, adheres closely to these concepts by virtue of the following attributes: (1) It provides secure fixation when properly applied; (2) It maintains bone ends in constant contact and does not hold them apart; and (3) It requires a minimum of surgical exposure with a minimum implantation of foreign material and, therefore, produces minimum devitalization of bone. The likelihood of complications, and their severity if they should occur, are thereby minimized.

Fracture of the Carpal Navicular. Diagnosis, Non-operative Treatment and Operative Treatment. Dr. Otto Russe [36]. (J. Bone and Joint Surg., **42-A**: 759–768, July 1960.)

The Enzymatic Treatment of Infected Wounds Following Orthopaedic and Traumatic Surgery; Including Several with Metallic Prostheses. Dr. Eugene E. Clifton [37] reported his results in the enzymatic treatment of thirty patients with chronic infections involving bones and joints. Included in this group were chronic infections with plates, screws, and femoral-head prostheses still *in situ;* chronic osteomyelitis with continued draining after removal of metallic implants; chronic osteomyelitis with continued draining after open fractures or surgical procedures; infected amputation stumps; and gangrene of the foot with osteomyelitis and miscellaneous conditions. The enzymes used in this series were human fibrinolysin (plasmin), a combination of bovine fibrinolysin and desoxyribonuclease, and hyaluronidase; fibrinolysin, however, was found to be the most effective agent for wound débridement. Although most of the thirty infections had been resistant to previous intensive therapy, twenty-one (70 per cent) healed on this treatment alone and four more healed after skin-grafting or secondary closure. Twenty-five infections were thus considered to have been treated successfully.

The author concluded that enzyme therapy should be used as an adjunct to surgical treatment as soon as adequate drainage has been instituted, and that it should be followed by secondary closure or skin-grafting as soon as the wound is clean.

Early Ambulation with Intertrochanteric Fractures. Dr. Earl P. Holt, Jr. [38], said that to accomplish the objective in the title of this paper, he uses a modified Jewett nail, consisting of a cannulated solid rod and a thickened plate, and applies it to the shaft of the femur by three 5/32 of an inch Barr screws and bolts with nuts. Several models of the device, which is in one piece, were tested for tolerance to loading and the latest appliance was found to tolerate a load of over 750 pounds. This is in contrast with the tolerance of the early Jewett nail (thirty-three pounds); the Smith-Petersen nail with Thornton plate (seventy-seven pounds); and a modern Jewett nail (up to 311 pounds). The estimated hip load in large adults, with a safety factor of two, was 800 pounds. The author described the insertion of this device into a hole drilled in the neck and head of the femur, with subsequent bolting of the plate to the shaft with Barr bolts.

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Eighty cases were described; all surviving patients had bone union. About one-third of the patients walked within four weeks and another third were able to walk at eight weeks. The balance of the patients included those who were too old to walk early, those who had died, and those who had complications. The complications included: one breakage of the nail; one infection; and one protrusion of the nail.

Dr. Holt also discussed the materials used in manufacturing the nails and the mechanical testing of all of the devices.

Tuesday, January 26

Progressive Fascial Ossification and Pleomorphic Sarcomas of Fascia: Juxtacortical (Parosteal) "Osteogenic" Sarcoma. Dr. J. S. Speed [39] and Dr. W. S. Gilmer, Jr. [40], analyzed five cases of juxtacortical (parosteal) "osteogenic" sarcoma in a study of the pathogenesis of this lesion. The patients had had the lesions for from two to thirteen years; two patients were observed for more than seven years before operation. In every instance, treatment was ablation of an extremity. One patient died with pulmonary metastases seven weeks after disarticulation of the humerus, but the others were free of disease from one to thirteen years later.

All lesions were grossly ossified masses intimately related to a large long bone; in four there was bone union with the cortex, although in every instance there was an area of cleavage between the mass and the cortex. Four lesions arose in areas of extensive muscle attachments; none arose in the "bare area" of the distal part of the femur. The authors did not believe that the majority of the reported lesions arose in the distal part of the femur, and felt that the significance of this location has been exaggerated. The theory of this tumor's origin in displaced embryonic tissues was also not endorsed.

Although the anatomy and histology of the lesions are exceedingly complex, the morphogenesis was reasonably simple: (1) Sustained progressive proliferation and hyperplasia of fascia and contiguous tissues, with subsequent ossification; (2) Gradual appearance of subtle atypical features within the hyperplastic tissue; (3) Eventual malignant transformation in several fields; and (4) Progressive differentiation, producing multiple histological types of sarcoma. Growth of the less differentiated tissue proceeds in the fashion characteristic of soft-tissue sarcomata, expanding into and compressing adjacent soft tissues and invading and destroying bone formed earlier in the development of the lesion. The complexity was thought to be due to the broad field in which these changes take place and the fact that they may occur either concurrently or sequentially in different areas. In addition, the pleomorphism of the malignant components far exceeded that seen in the usual bone-forming neoplasms.

The precise site of origin was considered a matter of speculation. Lesions situated in areas of muscle attachments begin as exostoses arising in the attachment of tendons and fascia; others begin as exostoses arising in the periosteum. The gross architecture of the lesions is a function of the site in which they arise.

The authors found, especially if there was an extended period of observation, distinctive roentgenographic changes before malignant transformation. Multiple oriented bars of ossification associated with a grossly irregular surface and absence of circumscription of the lesion denoted benign or borderline phases of the lesion (especially if these changes were associated with increasing radiopacity in the deeper portions of the lesion). With malignant change, the features were less characteristic, although the mere bulk of the lesion was in itself suggestive of a malignant state. Progressive refinement in the pattern of ossification with homogenization and less distinct or apparently purposeless orientation is also suggestive of malignant transformation. Sharply defined surfaces, irregular areas of radiolucency in otherwise dense bone (especially well within the substance of the lesion), and satellite opacities were associated with extensive malignant changes.

The authors questioned the propriety of designating these lesions as osteogenic sarcomata. It seemed proper to restrict this diagnosis to that group of rapidly growing, highly fatal bone-forming neoplasms of central origin, usually occurring in children and young adults. The lesions considered here, because of their entirely different behavior and prognosis, might more properly be identified simply as juxtacortical (parosteal) osteosarcomata.

Tendinitis of the Shoulder. Dr. Beckett Howorth [41] reviewed the anatomy of the shoulder and the pathology, etiology, diagnosis, and course of treatment of tendinitis.

The inflammatory and degenerative changes in the tendinous cuff appear to be due to friction and repeated small strains when the shoulder is subjected to sudden, jerky, and repeated movements. To a great extent these changes may be prevented by avoiding such motions and strains.

If calcareous material is present, it is, in the early stage, suspended in liquid and, roentgenographically, appears homogeneous and shaped like a cumulus cloud. In the chronic stage the deposit is granular and infiltrating, and the roentgenographic shadow fragmented and irregular in outline and density.

In early acute cases, the patient can obtain both improved motion and relief from pain and

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spasm by resting the arm, by the application of cold or ethyl chloride spray, and, perhaps, by radiotherapy. Sometimes there is partial or complete spontaneous absorption of the calcareous material.

Massage, diathermy, stretching, or manipulation is likely to increase pain, spasm, and limitation, and may damage the tendon cuff.

Aspiration, irrigation, or puncture of the deposit or, rarely, spontaneous rupture into the bursa may relieve pain because the material is drained and the tension relieved. Unless the cavity is drained at the same time, injections of novocain or xylocaine will relieve pain only temporarily.

Hydrocortone injection of the tender area of the tendon cuff, whether or not calcareous deposits are present, if done skillfully and accurately is safe, and often results in relief, particularly in the acute phase.

When hydrocortone injection fails, operative removal of the calcareous deposits is the surest, quickest, and most permanent method of relief, particularly in chronic conditions. Complete removal of the deposits is desirable for optimum healing of the lesion. Large, dense persistent deposits are best removed for the health of the tendon as well as for the relief of the patient.

Special exercises should be used with any of the treatments until full motion and strength have been restored, or until maximum improvement has been obtained. The patient should be carefully instructed in the proper use of the shoulder and arm to prevent aggravation or recurrence of the symptoms.

Kappa Delta Award Paper

A Correlated Clinical and Experimental Approach to the Etiology of Congenital Dislocation of the Hip. Dr. William S. Smith [42], Dr. Carl R. Coleman [43], Dr. Melvin L. Olix [44], and Dr. Richard F. Slager [45] used several interesting experimental approaches on puppies in their study of congenital dislocation of the hip. They showed that division of the ligamentum teres alone would not result in dislocation or in demonstrable changes in the acetabulum or the femoral head. However, when to this procedure was added the maintenance of the surgical dislocation of the femoral head, profound changes resulted: acetabular dysplasia and underdevelopment, covering of the acetabular cartilage by fibrous tissue, minor changes in the anteversion of the femoral neck, and formation of a false acetabulum. Removal of the femoral head and substitution of titanium objects in the acetabulum resulted in changes in contour of the acetabulum, which followed the general shape of the objects used. Excisional experiments were also reported in which capsule, acetabulum, and ligamentum teres were excised both individually and in combination. No dislocations occurred unless the ligamentum teres was cut, but some obliquity of the joint occurred if the cartilaginous rim was excised. In combination with either capsular or rim excision, cutting of the ligamentum teres resulted in dislocation. Surgical anteversion or retroversion of the femoral neck did not produce significant joint change.

Additional experiments were reported on the forces needed to dislocate the femoral head of the human infant when all the soft tissues, except the capsule and ligamentum teres, were removed. Constant stress of five pounds was sufficient to do this. In puppies, a similar experiment was done in which stretching of the capsule was evident visually, the average force needed to tear the capsule being twenty-nine pounds. In each of these experiments roentgenograms revealed dislocation of the hips.

The authors also discussed a statistical survey of 148 births in which dislocations of the hips were reported. Of these births an extremely large number was by breech presentation.

In conclusion, the authors said that many different factors can be recognized in congenital dislocation of the hip, no one of which adequately explains all of the facts.

Abdominal Fascial Transplants. An End-Result Study of 114 Cases. Dr. J. Vernon Luck [46] and Dr. Charles LeRoy Lowman [47] presented the first large-series, long-range, and end-result study of the Lowman abdominal fascial transplant. The end results were evaluated by Dr. Luck.

One hundred and fourteen abdominal fascial transplants were carried out for a variety of patterns of paralysis of the abdominal muscles. The results were good in sixty-seven procedures (58.8 per cent), fair in thirty-four (29.8 per cent), and poor in thirteen (11.4 per cent). The average follow-up period was 8.9 years.

The fascial grafts, as a group, have survived through the years. When they were used in children, they grew parallel with the growth of the child, and, from intermittent tension stresses, underwent remarkable degrees of hypertrophy. In the majority of patients, thoracopelvic stability and coordination have improved, and deformities have been prevented or diminished. The physiological benefits achieved include: improved function of gastro-intestinal viscera, increased vital capacity, and improved general health. These benefits, added to the improved thoracopelvic stability, re-

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sulted in increased endurance, improved posture in sitting and standing, and, in many instances, improved gait. The grafts are best when done early, prior to the appearance of fixed contractures.

The operations in this series were done by ten different surgeons. Poor results were usually attributable to errors in operative indication, defects in operative technique, or a breakdown of postoperative management. The over-all results are good.

The many opportunities to utilize fascial grafts for breaks in human kinetic chains deserve wider recognition and further study, both clinical and experimental. The authors hope that this report will stimulate interest in this important and rewarding field.

Stabilization of the Collapsing Spine. Dr. Alice L. Garrett [48], Dr. Jacquelin Perry [49], and Dr. Vernon L. Nickel [50] presented a study of thirty-eight patients who had extensive spine fusion for collapse of the spine, the result of muscle weakness after poliomyelitis or transverse myelitis.

Those patients with residual motor power in the lower extremities were greatly benefitted because their tolerance for walking or standing was extended. Upper-extremity function was increased in most (75 per cent) patients because of improved trunk balance. Endurance for sitting or walking, resistance to atelectasis, and pulmonary infection were improved in almost all of the patients who were limited in this respect.

The authors recommended prophylactic fusion on patients whose spines are collapsing because of extreme muscle weakness, the instability alone being the indication for operation.

Paralytic Scoliosis from the Aspect of Prognosis and Associated Muscle Paralysis. Professor J. I. P. James [51] reviewed a series of 235 paralytic, mature, untreated scoliotic spines. When this series was compared with Sharrard's series of 280 cases of poliomyelitis without scoliosis the following observations and prognostic criteria were apparent.

Scoliosis never develops in the absence of trunk paralysis. Paralysis of upper and lower extremities had no effect on the development of scoliosis, and if the paralysis occurred in the adult, a structural curve did not develop.

Analyzing the location of the curve aided in prognosis.

High thoracic primary curves: These curves with the apex at the first or second thoracic vertebra have a bad prognosis. Fourteen of twenty untreated patients had curves of greater than 100 degrees with the upper border of the trapezius elevated, the head and neck displaced to one side, rotation of the thoracic vertebra, and prominence of the transverse processes, resulting in an ugly curve.

Thoracic curves: Sixty-eight of eighty-six untreated spines had a right curve. This curve is longer than its counterpart in the idiopathic variety. The muscles necessary to produce compensatory curves are often too weak to do this. Nineteen or thirty-three untreated curves of this type were greater than 70 degrees.

Thoracolumbar curves: Long curves were not exceptional in this group. Seventeen of twenty-seven untreated spines had curvatures greater than 70 degrees.

Lumbar scoliosis: There are basically two types of lumbar curve. One is a long, gradual curve, which is slow to develop and is associated with severe symmetrical paralysis of the long muscles of the trunk. The second type is present when there is a gross inequality of the lateral flexors; here a shorter and sharper curve develops. Eleven of sixteen untreated spines had curvature greater than 70 degrees.

Double primary curves: Twenty-one patients had double primary curves. The curves arose from paralysis of the lateral flexors on the opposite side. The prognosis could not be determined in such a small series.

The curves developed in the vast majority of patients within two years of the original attack of poliomyelitis. The higher the primary curve, the worse the prognosis. The severity of the prognosis is greater with paralytic than with idiopathic scoliosis. The younger the patient with poliomyelitis, the greater is the likelihood that curvature will develop; the more unequal the trunk musculature, the worse the prognosis.

From this study, the author concluded that shoulder paralysis has nothing to do with the development of curvature in paralytic scoliosis.

Eighty-four of 129 thoracic scolioses had normal erector spinii, suggesting that these muscles at this level have no importance in the development of the curvature. Paralysis of the abdominal muscles had no apparent effect on the direction of the curve.

The function of the intercostal muscles was tested at the apex of the thorax, at the nipple line, and at the base. If the hands encircle each side of the chest at the moment of expiration the thumbs touch in the mid-line. As inspiration occurs it will be found in the presence of unilateral weakness

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that one thumb moves perhaps one inch away from the middle, and the other only one-quarter of an inch. By this means, asymmetry of movement in the intercostals was demonstrated. In the high thoracic curves, all spines showed paralysis of the intercostals on the convex side but none on the concave side. This was also true for the thoracic curves. Further proof of this fact was obtained in sixteen patients who had delayed onset of their high thoracic curves. Paralysis of the intercostals was demonstrated in all these patients, there being no other associated trunk paralysis. It was also noted that in paralytic scoliosis the ribs are crowded together and droop almost vertically on the convex side. This is directly opposed to idiopathic scoliosis, where they tend to fan out. A paralyzed intercostal is apparently unable to hold up the ribs. The ribs involved are sharply correlated with the distribution of the paralysis of the intercostals, except in the low thoracic and thoracolumbar curves. Presumably, this is due to the complexity of the associated erector spinae, anterior abdominals, and lateral flexors of the abdomen, the intercostals, and the diaphragm, all acting at the junction of the thorax and the abdomen making accurate muscle analysis impossible.

The author agreed with previously published work on the importance of the lateral flexors of the spine in the production of low lumbar curves. This is borne out in his series in which twenty out of twenty-five spines showed weakness of the muscle on the convexity of the curve. None had weakness on the concave side. Gravity does not have much influence on the thoracic curve; yet, on the lower curves its influence is highly important. Muscle weakness in the legs had no apparent correlation with spinal curvature; likewise, leg shortening had no appreciable effect. Contracture of the tensor fasciae latae in the absence of trunk paralysis had no effect on curvature.

Attempted Epiphyseal Arrest of the Spine by Intervertebral Fusion in Scoliosis. Dr. H. Relton McCarroll [52] and Dr. William S. Costen [53] said that the reports of experimental work by Haas, Bisgard and Musselman, Nachlas and Borden, and Ponseti and Baird suggested that idiopathic scoliosis may result from some primary disturbance in the vertebral epiphyseal plates. The mild wedging of vertebral bodies seen in the anteroposterior roentgenogram of a young patient with early idiopathic scoliosis also suggests this possibility. If this is true, it may be logically reasoned that unilateral epiphyseal arrest, performed on the side of convexity, may represent a means of treatment.

The authors performed operations on six children; the procedure consisted in excising a block of bone from two or three vertebrae on the convex side of the curve, curetting the adjacent portion of the epiphyseal plates, and inserting an inlay type of bone graft, obtained from a rib which was removed to gain the exposure. The children were allowed up in a Hoke corset two weeks after operation.

Two operations, performed in the lumbar area for scoliosis secondary to hemivertebra, were not included in the report. Of the four operations performed in the thoracic spine, three were on children, eight to ten years of age, with idiopathic scoliosis. The fourth was on a five-year-old child with scoliosis associated with a neuroblastoma, arrested by irradiation. Follow-up studies made from two and one-half to three years after operation showed that in each instance the operation failed to accomplish the purpose for which it was performed. One or more pseudarthroses developed in all patients. There was no evidence that growth arrest occurred, and in each patient there was further progression of the curve.

The epiphyseal plates removed from these children with idiopathic scoliosis were compared with those obtained from three children of comparable age—one with a normal spine who died as the result of an accident, one who was operated on because of a hemivertebra, and one who died with congenital fibrocystic disease. In the normal child, the vertebral epiphyseal plate consisted of a thin layer of cartilage in which the cells were arranged, for the most part, in regular and uniform columns. In the patient with idiopathic scoliosis, however, this smooth and orderly arrangement of the cartilage columns was not present. In most areas only a few scattered and irregular nests of cartilage cells could be found. This change is a relative one with the normal child, showing the uniform columnar arrangement of cartilage cells primarily and only a few areas of mild irregularity. In the patient with idiopathic scoliosis, however, the picture primarily is one of confusion and irregularity in arrangement of cartilage cells, with only an occasional area in which the normal uniform pattern is preserved. In the patient with fibrocystic disease, there was extreme distortion of the columnar arrangement of cells.

Lumbar Discography—Its Technique, Applications and Limitations. Dr. George T. F. Rahilly [54].

Wednesday, January 27

Functional Evaluation of Sciatic Nerve Injuries. Dr. D. Kay Clawson [55] reported the functional end results of 328 cases of sciatic-nerve lesions treated by Professor H. J. Seddon and his

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associates in England, at the Winfield Morris Orthopaedic Hospital, Oxford, and the Royal National Orthopaedic Hospital, London. The patients were evaluated three to eighteen years after treatment; only those with neurotmesis (complete nerve severance) or axonotmesis (nerve crush) were reviewed. Patients with significant pain, limitation in walking, or inability to return to previous employment were considered to have unsatisfactory results. On this basis, 36 per cent of patients with sciatic paralysis, 11 per cent of patients with lateral popliteal (common peroneal) paralysis, and 13 per cent of patients with medial popliteal (tibial) paralysis were in the unsatisfactory group. There was a better correlation between sensory recovery and function than between motor recovery and function.

The factors influencing recovery were age, pain, vasomotor and nutritional disturbances, paresthesia, overresponse (exaggerated and painful response to an ordinary stimulus), and pressure sores or ulcerations. Fifty-three per cent of the patients complained of pain; 33 per cent had vasomotor and nutritional changes; 21 per cent had paresthesiae; and 35 per cent had overresponse. Fifty-four per cent of patients with medial popliteal lesions and 3.5 per cent of patients with lateral popliteal lesions had the troublesome phenomenon of overresponse. This is often so disabling when it is present on the sole of the foot that it is unwise to attempt suture of the posterior tibial nerve, except in children or, occasionally, in the adult, if conditions are ideal.

Pressure sores and ulcerations occurred in 14 per cent of patients, primarily in those in whom both divisions of the sciatic nerve were damaged. However, of ten patients continuing to have ulcerations longer than four years, all had fixed deformity as a main contributing factor.

The author analyzed the reconstructive techniques employed. Twenty Lambrinudi arthrodeses for foot-drop were carried out; 50 per cent of the patients were satisfied with the end result. Only five operations were successful, using as criteria for success the elimination of foot-drop, no increase in pain, and as good function as before surgery. In foot-drop from lateral popliteal lesions, the procedure of choice seemed to be the transfer of the posterior tibial tendon through the interosseous membrane. In total sciatic paralysis, the wearing of a light toe-raising appliance appeared to be preferable to a Lambrinudi arthrodesis. The disadvantages of rigidity in the anesthetic or partially anesthetic foot were emphasized; the best functional results occurred in patients with supple feet.

Ten patients had amputations because of fixed deformity, pressure sores, or pain. The patients who had amputation performed for fixed deformity or pressure sores were pleased with the result. The three patients whose amputations were for pain were not satisfied with the procedure because the pain had not been alleviated.

In discussion, Dr. Paul J. Collopy [56] noted that such lesions were rarely seen in private practice. Most of the cases from the Milwaukee area were seen at the Wood, Wisconsin, Veterans Administration Hospital. The main causes of sciatic-nerve lesions were from accidental gunshot wounds, compound fractures, fracture-dislocations of the hip, and, occasionally, pressure sores from cast or traction. Since 1946, on the orthopaedic surgery service of the Veterans Hospital, there were twenty-three cases of foot-drop, fifteen of which were due to sciatic-nerve injuries. Twenty per cent of the patients with traumatic dislocation of the hips had sciatic-nerve injuries. The most common and satisfactory surgery for foot-drop deformity was a Lambrinudi triple arthrodesis. The most consistent pain was over the plantar surface of the foot, over the metatarsal arch. Transfers of the posterior tibial tendon were not done in adults. Dr. Collopy wondered if the transfers of the posterior tibial tendon in the adults were active or if they acted as a tenodesis. Painful hammertoes were usually corrected with interphalangeal arthrodeses or proximal phalangeal resections.

Because there is a great variation in a patient's motivation, Dr. Collopy felt that the reevaluation of sciatic-nerve injuries, as carried out by Dr. Clawson, was important to determine whether more or less surgery is indicated in the final rehabilitation of patients with these injuries.

The Collagen (Mesenchymal) Disorders—Their Diagnosis and Current Trends in Their Management. Dr. William K. Ishmael [57] summarized the principal clinical characteristics of rheumatoid arthritis, lupus erythematosus, scleroderma, periarteritis nodosa, and dermatomyositis. The management of these diseases from the medical aspect includes a number of measures distinct from the usual orthopaedic management—physical therapy and protection of the patient from stress. Medically, analgesics, tranquilizers, soporifics, and psychic energizers are frequently needed. Control of streptococcal infections also is often required. The glucocorticoids, administered in the appropriate fashion, also have a place. Similarly, corticotropin may be used in more severe cases. Nitrogen mustard has a place in the very severe disorders, and narcosynthesis was used where psychomotor problems interfered with recovery. The antimalaria drugs are also to be recommended in many instances.

Problems in the Recognition and Treatment of Congenital Convex Pes Valgus. Dr. Charles H. Herndon [58] and Dr. Clarence H. Heyman [59] discussed the diagnosis and treatment of congenital vertical talus, on the basis of their experience with twenty-five patients.

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58. 2065 Adelbert Road, Cleveland 6, Ohio.
59. 2425 North Park Boulevard, Cleveland Heights 6, Ohio.

The clinical appearance of this deformity may be similar to congenital calcaneal valgus, but there are important differences. In congenital vertical talus, the fore part of the foot is abducted and tilted upward, the sole is convex, the foot cannot be inverted, and the prominent talar head is felt in the sole and cannot be reduced by either pressure or manipulation. The foot is not in a position of excessive calcaneus at the ankle joint. The Achilles tendon is tight, and the calcaneus is tilted downward. Roentgenographically, the head of the talus is dislocated medially and downward and the scaphoid articulates with the dorsal aspect of its neck.

The method of treatment depends on the age of the patient. Although manipulation and plaster immobilization may attempted, reduction by closed methods is extremely difficult—if not impossible—to achieve in infants. Open reduction, however, performed on six children gave good results in five; in four of these five internal fixation was obtained by pins. Avascular necrosis seems to be developing in one patient. In the older children relief from symptoms was achieved by excision of the bone prominence or correction of the deformity was obtained by triple arthrodesis, a difficult procedure in this entity.

Talipes Equinus Correction in Cerebral Palsy. Dr. Carl D. Martz [60]. (J. Bone and Joint Surg., **42-A:** 769–776, July 1960.)

Correction of the Deformed Foot in Hereditary Peroneal Palsy (Charcot-Marie-Tooth Type). Dr. Chalmers R. Carr [61] discussed the foot surgery performed to correct the cavovarus deformity and soft-tissue contractures occurring in the Charcot-Marie-Tooth type of hereditary peroneal palsy.

The disease itself is progressive up to a point, but then tends to become static or stationary. It is after this peak of progression that corrective surgery on the foot has been found valuable; it lessens the deformity and increases the power of the uninvolved muscles, with the result that the patient can wear standard shoes and can walk better with less fatigue.

There are two basic considerations when performing surgery for this condition: (1) the correction of the bone deformity by biplane wedge osteotomy of the mid-tarsus with subtalar arthrodesis of the foot in the corrected position; and (2) transfer of the posterior tibial tendon from its normal attachment to the mid-tarsus after rerouting it to the mid-foot through the interosseous membrane between the tibia and fibula.

The Hip Shelf Operation in Children. Dr. David M. Bosworth [62], Dr. J. William Fielding [63], Dr. William A. Liebler [64], Dr. Paul Cohen [65], Dr. Hirosi Ikeuchi [66], and Dr. Tadao Ishizuka [67] reported an end-result study of eighty-two hip-shelf operations performed on sixty children with instability of the hip secondary to a variety of conditions including, among others, congenital dislocation and subluxation, poliomyelitis, old suppurative arthritis, and cerebral palsy. The ages of the children at operation ranged from one to fourteen years, with an average of 4.6 years. The duration of follow-up ranged from two to twelve years, with an average of 6.3 years. Five of the operations performed before 1946 consisted in turning down a section of the outer table of the ilium. All of these shelves absorbed, but the result was satisfactory in two of these hips.

In the remaining operations the authors so-called snap-in type of procedure was performed: The lateral edge of the graft is placed under the partially detached reflected head of the rectus femoris muscle and the medial end of the graft, taken from the outer table of the ilium, is pushed down until it snaps into a slot in the ilium placed at the attachment of the superior capsule to the acetabular margin.

By this procedure the graft is held so firmly that no postoperative immobilization is required, except for bandaging the legs together for one to two weeks .No attempt was made to reduce dislocations in the older children, the shelf being placed above the false acetabulum. No redislocations occurred except in the patients with cerebral palsy and one patient with syringomyelia. No adverse effect on hip function resulted from the procedure, and function was improved in the successful cases. With time, the shelf hypertrophied and the superior acetabulum became wider, thus forming a good ledge of bone over the femoral head.

The authors concluded that the procedure is of value for all types of hip instability, regardless of the cause, except instability due to cerebral palsy; that the operative technique is the main factor that determines the result; that the age of the child at operation has little influence on the result; and that the procedure is invaluable in a child in whom local conditions demand stabilization of the hips.

The full paper should be read to avoid false impressions as to indications and results.

60. 23 East Ohio Street, Indianapolis 4, Indiana.
61. 1822 Brunswick Avenue, Charlotte 7, North Carolina.
62. 742 Park Avenue, New York 21, N. Y.
63. 139 Depew Street, Dumont, New Jersey.
64. Lenox Hill Hospital, New York 21, N. Y.
65. St. Vincent's Hospital, Staten Island, New York.
66. St. Giles Hospital, Brooklyn 13, New York.
67. 691, 3-chome, Shimo-Meguro, Meguro-Ku, Tokyo, Japan.

Muscle Origin Release Operation for Congenital Elevation of the Scapula. Dr. Joe W. Woodward [68] presented a method of surgical correction for congenital elevation of the scapula. It differs from methods previously reported in that the scapula is lowered by releasing the origin of the muscles attached to its vertebral border rather than at the insertion. After the release of these structures the scapula can be lowered without undue downward pressure upon the shoulder girdle. It is maintained in its lowered position by suturing the margin of the muscle sheet at a lower level to the spinous processes and interspinous ligaments. Effort is made to bring the scapula down so that the spine is at the same level as that on the opposite side, rather than lowering it so that the inferior angle is opposite the normal side since if hypoplasia of the scapula is present this will represent overcorrection and create overstretch of the brachial plexus. A Velpeau bandage is applied after meticulous skin closure is carried out. Early ambulation and a short hospital stay are usually possible.

Six patients have been operated on by this method, with the only complications being broadening of the scars in some instances and, in one patient, overcorrection which resulted in transient brachial-plexus palsy. Marked improvement in function of the neck and shoulder girdle was observed in all patients, along with a gratifying degree of cosmetic improvement. The patients were operated on by five different surgeons, all using the technique described; in each instance the surgeon said that he would use this method of correction again in the treatment of congenital elevation of the scapula.

Thursday, January 28

Medical Color Photography Simplified. Dr. Ben R. Wiltberger [69] presented a group of simple methods by which the medical photographer could obtain better illustrations of medical material.

He delineated the principles of color balance and described the preparation and copying of roentgenograms, the photography of surgical procedures, photomicrography, and the preparation or copying of transparencies of gross specimens. For comparative purposes the various types of films available and their adaptability to medical photography were illustrated by actual photographic set-ups.

Operative Reconstruction of Sinus Tarsi in Old Fractures of the Calcaneus. Dr. Joseph E. Milgram [70] discussed post-traumatic mechanical derangements in the area of the lateral malleolus. When a small piece of bone in that area has been torn off the calcaneus or the talus it may be painful because of interference with the motion of the malleolus on the talus. The author performed removal of the fragment and said that four such procedures were successful. He suggested they arose from momentary subtalar joint subluxation. Many fibular avulsions arise from a momentary subluxation of the ankle joint and, as has been reported in the literature, seldom require operative intervention.

When there has been a crush fracture of the calcaneus, the buckling and the bone reaction of the outer table interfere with and displace the peroneal tendons or, by bone impingement, interfere with talomalleolar movement. The treatment advocated is osteotomy of the outer table of the calcaneus, countersinking it into a prepared calcaneal defect, usually with subtalar or triple arthrodesis if the mid-tarsal joints are involved. The objective of this operation is to depress the protuberant bone without leaving a surface that will proliferate new bone after operation. The author's series of over twenty procedures in selected cases of fibular impingement was attended with exceptionally good results in that lateral pain was regularly relieved. The exact extent of the surgery differed with the anatomical extent of fibular impingement in individual patients and included subtalar arthrodesis or triple arthrodesis.

The Relief of Intractable Arthritic Pain by Extended Sympathetic Denervation: A Five-Year Study. Dr. Robert Herfort [71] said that the principal source of disability in most patients with chronic arthritis is pain in the weight-bearing joints. During the past five years the author performed so-called extended sympathetic denervation in fifty-two patients with advanced painful rheumatoid arthritis and osteo-arthritis of the hip or knee joints, or both. The surgery consists in a retroperitoneal resection of the lumbar sympathetic trunks from the superior margin of the common iliac vessels to the second lumbar vertebra; it includes excision of accessory ganglia on the rami communicantes and severance of decussating fibers in the retro-aortic prevertebral plexus. This operative procedure in middle-aged and elderly arthritic invalids has resulted in no morbidity and no mortality. In the immediate postoperative period the patients consistently exhibited relief of pain and improvement in mobility and functional capacity. The patients have been followed for periods up to five years after surgery; the relief of pain and improved range of motion have been maintained during this period, and there have been no undesirable effects. Neuropathic disorganization of the affected joints has not occurred.

68. 2220 Austin Avenue, Waco, Texas.
69. 50 West Gay Street, Columbus 15, Ohio.
70. 1919 Madison Avenue, New York 35, N. Y.
71. 5 Old Mamaroneck Road, White Plains, New York.

Dr. Herfort added that the principal afferent pain pathways from the articular surfaces of the hip, knee, and ankle joints traverse the lumbar sympathetic trunks.

Treatment of Vitamin "D" Resistant Rickets. Dr. Warren G. Stamp [72], Dr. Thomas E. Whitesides [73], Dr. Morton Field [74], and Dr. George E. Scheer [75] presented a study of twenty children with vitamin D-resistant rickets treated between 1949 and 1959. The authors attempted to prevent dwarfism and deformities by early adequate vitamin D therapy. They found that elevation of the low serum phosphorus levels and reduction of the high alkaline phosphatase were obtained when massive doses of vitamin D were given. However, this response was complicated by hypercalcemia, manifested clinically in four patients. When the serum calcium levels were maintained near 12 milligrams per 100 milliliters the serum phosphorus invariably fell below 4 milligrams per 100 milliliters. At this level roentgenograms would show improvement in the zones of provisional calcification, but in none of the patients was there a normal skeletal restitution. The effect of treatment on the rate of growth and recurrence of bone deformity was difficult to evaluate clinically. Only two children were in the normal-height group (Wetzel grid classification), the remainder being well below normal. Recurrences of deformities did occur during treatment.

Metabolic studies were made to (1) distinguish whether a primary tubular defect or an extrarenal defect was the cause of the disease, and (2) determine the cause of failure of vitamin D as a cure. The tubular resorption of phosphate in normal subjects and in rachitic patients was determined before administration of vitamin D. Base-line values of tubular resorption of phosphate were normal in the normal group, but lower in the rachitic group. When calcium infusions were given, the tubular resorption of phosphate rose only slightly in the normal group but rose sharply in the rachitic group, eventually reaching a normal level. The tubular resorption of phosphate was measured in both the normal group and the rachitic group after seven days of vitamin D treatment; the values were normal in the normal group and low in the rachitic group. After calcium infusions, however, the tubular resorption of phosphate rose in the rachitic group but declined in the normal group.

The authors said that these findings were used to support the following hypotheses: (1) The tubular resorption of phosphate in vitamin D-resistant rickets is normal; (2) Phosphaturia and low tubular resorption of phosphate are presumably due to secondary hyperparathyroidism; (3) The failure of vitamin D to restore serum phosphorus to normal is due to the phosphaturic effect of the vitamin itself; and (4) The inability to restore serum phosphorus to normal is responsible for the failure of cure in rickets.

Slipped Capital Femoral Epiphysis in Negroes. Dr. Caesar Orofino [76], Dr. John Innis [77], and Dr. Cedric W. Lowrey [78] searched the records of the Charity Hospital in New Orleans for case reports of slipped capital femoral epiphysis in the Negro and found ninety-five such reports. Thirty-two of the Negroes had bilateral involvement, making a total of 127 hips studied.

In the first group—twenty hips—there was either no treatment or treatment by subtrochanteric osteotomy or cup arthroplasty; all results were bad in this group. In the second group—fifty-one hips—all hips were treated by internal fixation *in situ* of the slipped epiphysis; results were satisfactory in forty hips. A third group—thirty-three hips in which the slip was more than one-third the width of the neck—was treated by cuneiform osteotomy with replacement of the femoral head in anatomical relationship; results were unsatisfactory in twenty-two hips and satisfactory in eleven. The fourth group—twelve hips—included hips treated by traction, by immobilization, and by closed reduction; results were unsatisfactory in eleven.

There were fifty-eight patients in whose hips there was a slip of less than one-third of the diameter of the neck; forty-one patients had satisfactory results and eleven, unsatisfactory.

Thus, in a series of 127 hips, only fifty-nine patients reached the age of eighteen years without incapacitating pain accompanied by degeneration of the joint and limitation of motion. The prognosis for a good result in Negroes with slipped epiphysis is therefore less favorable than in Caucasians. The degree of slip also had a definite bearing on the end result.

Racial Factors in Slipped Femoral Epiphyses. Dr. Byron A. Genner, III [79], Dr. William M. Roberts [80], Dr. George R. Miller [81], and Dr. R. Beverly Raney [82] reported their experience with the treatment of slipped femoral epiphysis of 147 patients, ninety-two of whom were

72. Barnes Hospital, St. Louis 10, Missouri.
73. Barnes Hospital, St. Louis 10, Missouri.
74. Barnes Hospital, St. Louis 10, Missouri.
75. 634 North Grand Avenue, St. Louis 3, Missouri.
76. 3503 Prytania Street, New Orleans 5, Louisiana.
77. 914 West Cannon Street, Fort Worth, Texas.
78. 622 Lauricella, New Orleans, Louisiana.
79. Wright-Patterson Air Force Base, Dayton, Ohio.
80. North Carolina Orthopedic Hospital, Gastonia, North Carolina.
81. Realty Building, Gastonia, North Carolina.
82. North Carolina Memorial Hospital, Chapel Hill, North Carolina.

Negro and fifty-five, white. Fifty-three of the Negro patients were male, as were thirty-nine of the white patients. Fifty per cent of the Negro patients showed bilateral involvement, whereas only 25 per cent of the white patients had both hips involved. Most of the white patients were obese, whereas many more Negroes were of average weight. Most of both groups of patients showed a gradual slipping of the epiphysis (Class I and II), but the Negroes showed more narrowing of the joint space.

End-result studies were made of twenty Negro patients (thirty hips) and eighteen white patients (twenty-two hips), with the follow-up ranging from two to twenty-two years after onset of disease. In the hips of the Negro patients good results were shown in seven; fair results in nine; and poor results in fourteen. In the hips of the white patients there were twelve good results, six fair results, and four poor results. Thus, in the Negro patients the results were good in only 23 per cent of the hips, whereas in the white patients 54 per cent of the hips showed good results.

In view of the high incidence in the Negro of bilateral involvement and in view of the high percentage of poor end results, the authors recommended a cautious surgical approach to the involved hips and prophylactic fixation of the uninvolved hip in the Negro patient.

Ischio-Femoral Arthrodesis. Dr. David G. Vesely [83] reported the results of forty-one ischiofemoral arthrodeses of the hip performed during the years 1947 to 1958. Tuberculous involvement of the hip was found in approximately 65 per cent of the patients. The operative procedure followed closely Brittain's original technique.

All cases of non-fusion were in patients under twenty years of age. Thirty-five of the forty-one hips became solidly fused. There was one cardiac arrest. Fracture of the graft in one patient and sequestrectomy of the graft in two patients did not preclude union of the osteotomy site or fusion of the hip joint. Fusion was obtained in 80 per cent of the patients, the majority being in the older-age groups (from twenty to forty years). The most obvious technical complications in the series were failure to secure solid insertion of the tibial graft into the ischial slot and incomplete femoral osteotomy. The only sciatic-nerve damage was temporary peroneal damage from excess traction on the sciatic nerve during the posterior approach.

In discussion, Dr. Lenox D. Baker [84] mentioned that in several of the patients the graft appeared to play no part in the hip fusion, and he wondered if the osteotomy were not the main aid to fusion. Dr. Baker emphasized that he still believed, with all things being equal, that hip fusion was the best treatment for disabling unilateral hip pain or disease, and that a fixed graft with osteotomy was the fusion operation of choice (the site of graft to depend on the findings of the individual case). He stated that he has been impressed with the importance of putting the hip at rest by osteotomy and adequate cast protection to obtain healing—the Brittain procedure.

Hematogenous Pyogenic Vertebral Osteomyelitis. Dr. Alexander Garcia, Jr.[85], and Dr. S. Ashby Grantham [86]. (J. Bone and Joint Surg., **42-A:** 429–436, Apr. 1960.)

83. 1800–12th Avenue South, Birmingham 5, Alabama.
84. Duke University School of Medicine, Durham, North Carolina.
85. 180 Fort Washington Avenue, New York 32, N. Y.
86. 326 West 165th Street, New York 32, N. Y.

The following were approved by the Executive Committee for transfer to Emeritus Membership: Dr. Arthur Griswold, Bridgeport, Connecticut; Dr. Edward LeCocq, Seattle, Washington; and Dr. Charles E. Irwin, Atlanta, Georgia.

The following list of applicants was approved by the Executive Committee for Active Fellowship:

Arthur Joseph Abelson, M.D., Canton, Ohio
Raymond John Adams, M.D., Seattle, Washington
Billy Mack Adamson, M.D., Newport Beach, California
Emmett Altman, M.D., Jamaica, Long Island, New York
Harlan B. Anderson, M.D., Casper, Wyoming
Edward A. Attix, M.D., Hattiesburg, Mississippi
George N. Austin, M.D., Carswell Air Force Base, Texas
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Thomas J. Coleman, M.D., Monterey Park, California
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James Joseph Conners, M.D., Jacksonville, Florida
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Bernard Cooperman, M.D., Long Beach, California
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James Bruce Cunningham, M.D., Ventura, California
Roger W. Davis, Jr., M.D., Hartford, Connecticut
James Stewart Deakins, M.D., Philadelphia, Pennsylvania
Lovick Edsel Dickey, M.D., Macon, Georgia
John Henry Doherty, M.D., Bronx, New York
John Joseph Dowling, M.D., Philadelphia, Pennsylvania
Bernard John Drury, M.D., Santa Barbara, California
William Fisher Enneking, M.D., Jackson, Mississippi
Robert W. Florence, M.D., Tacoma, Washington
Robert Edgar Forbis, M.D., Albuquerque, New Mexico
Robert Martin Foster, M.D., Youngstown, Ohio
Edward C. Froning, M.D., San Mateo, California
Frank L. Golbranson, M.D., Bremerton, Washington
Antonio George Guerrieri, M.D., Pittsfield, Massachusetts
Manuel Guzman-Acosta, M.D., Santurce, Puerto Rico
Ray Allen Haag, M.D., Bay Shore, Long Island, New York
Arnold Haber, Jr., M.D., Nashville, Tennessee
Richard Glenn Hamill, M.D., Pueblo, Colorado
Paul Randall Harrington, M.D., Houston, Texas
Ernest Rudolph Hartman, M.D., Biloxi, Mississippi
John Terrence Hayes, M.D., Ann Arbor, Michigan
John Walter Hazlett, M.D., Kingston, Ontario, Canada
Robert Samuel Heidt, M.D., Cincinnati, Ohio
Walter J. Helsing, M.D., Beaver, Pennsylvania
John A. Hennessen, Jr., M.D., Washington, D. C.
C. Hugh Hickey, M.D., Milwaukee, Wisconsin
John M. Higginbotham, M.D., Birmingham, Alabama
Sam Winston Huddleston, M.D., Johnson City, Tennessee
Walter Indeck, M.D., Minneapolis, Minnesota
John C. Ivanoff, M.D., Riverside, California
Verner Stanley Johnson, M.D., Worcester, Massachusetts
Richard S. Kamil, M.D., Detroit, Michigan
Edward Horan Kelly, M.D., St. Paul, Minnesota
Paul R. Kempf, Jr., M.D., Van Nuys, California
Robert Kerin, M.D., New Haven, Connecticut
Ray Ernest King, M.D., Shreveport, Louisiana
Benjamin Ford Kitchen, Jr., M.D., Houston, Texas
Louis Peter Kivi, M.D., Ann Arbor, Michigan
Edward M. La Fond, M.D., St. Cloud, Minnesota
John F. Lance, Jr., M.D., Wichita, Kansas
Andrew Wilson Lawrence, M.D., Huntington, Long Island, New York
Thomas C. Leinbach, M.D., Reading, Pennsylvania
James Thomas Leslie, Jr., M.D., San Antonio, Texas
Leon Levine, M.D., Schenectady, New York
James Drennan Lowell, M.D., Boston, Massachusetts
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Wallace McMillan Lyall, M.D., Long Beach, California
Angus Hugh MacMillan, M.D., Hamilton, Ontario, Canada
Richard A. Mayo, M.D., Boston, Massachusetts
L. Bruce Meyer, M.D., Monterey, California
Owen Edward Miller, M.D., Milwaukee, Wisconsin

Norman Paul Morin, M.D., Lake Charles, Louisiana
George J. Murphy, M.D., San Pedro, California
Horace R. Murphy, M.D., Little Rock, Arkansas
Robert Edward Musgrave, M.D., Danville, Virginia
Newton C. McCollough, M.D., Orlando, Florida
James G. McFaddin, M.D., Bristol, Tennessee
John Francis McGonigle, M.D., Los Angeles, California
Marvin W. Nelson, M.D., Racine, Wisconsin
Roland F. Neumann, Jr., M.D., Minneapolis, Minnesota
Esmond Douglas Vere Nicoll, M.D., Charlottesville, Virginia
Albert J. Novotny, M.D., Peoria, Illinois
John J. O'Connor, Jr., M.D., Bay Shore, Long Island, New York
George E. Omer, Jr., M.D., Fort Riley, Kansas
Richard L. O'Neil, M.D., Binghamton, New York
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Wesley Ellington Scott, Jr., M.D., Rockville Centre, Long Island, New York
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Charles Kazimir Skreczko, M.D., New Haven, Connecticut
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David Kimball Webster, M.D., Staunton, Virginia
Robert S. Wedeen, M.D., Coatesville, Pennsylvania
N. James Wilson, M.D., Medford, Oregon
Daniel McCoy Winters, M.D., Red Bank, New Jersey
Milton A. Wohl, M.D., Philadelphia, Pennsylvania
William David Wright, M.D., Greensboro, North Carolina
Robert Michael Yanchus, M.D., New Kensington, Pennsylvania
John Earl Young, M.D., Indianapolis, Indiana
Robert W Youngblood, Jr., M.D., San Jose, California

The Role of the Surgeon in the Certification of the Individual Orthotist-Prosthetist and of the Facility in Which He Works. Lester A. Smith[1], Assistant Director of the American Board for Certification in Orthotics and Prosthetics, Inc.; John A. Debender, C.O.; Alfred Denison, C.P.; George H. Lambert, C.O. and P.; Paul E. Leimkuehler, C.P.; Howard R. Thranhardt, C.P.; Richard Bidwell, C.O. and P.; Howard R. Reinherz, C.O.; and Ted W. Smith, C.O. and P., presented a survey of the ways in which the orthopaedic surgeon enters into the training, counseling, and examining of the applicant for certification in orthotics and prosthetics.

Panels on "The Artificial Muscle", "Applied Functional Bracing", and "The Below-Knee Adjustable Leg" were presented as examples of the complicated appliances of today for which the skill of the certified orthotist-prosthetist is required.

It was pointed out that certification is a voluntary, standards-raising movement; The American Academy of Orthopaedic Surgeons has, from the beginning, been a major factor in its establishment and continuance. Three of the seven-man Board of Directors of the Certification Board are nominated by the Executive Committee of The Academy (three others are nominated by the American Orthotics and Prosthetics Association; one is nominated by the Advisory Council, elected by the 1,100 certified orthotists and prosthetists).

The picture panels in the exhibit illustrated how the surgeon assists certification by advising the novice orthotist and prosthetist. The surgeon, through his control of the prosthetics-orthotics clinic, is able to observe the candidate for certification and to give him his first lessons in clinic team procedure.

The surgeon plays an important role in the annual examination of candidates. By regulation of the American Board for Certification, each candidate is examined by a team of three examiners, one of whom must be an orthopaedic surgeon and a member of The Academy. Finally, the surgeon, through his encouragement of the certified facility by recommending its use, assists the ethical certified facility in maintaining its standards and withstanding the effects of unethical competition.

The Primary Cause of the Lumbo-Sacral Disc Syndrome. Dr. Roger Anderson[2] and Dr. Ivan Loughlen demonstrated by illustrations and models of anatomical, pathological, embryological, and physiological tenants that the disabling low-back and herniated-disc syndromes were different stages of the same entity. A twelve-year study of over 2,000 fully exposed posterior articulations at the time of surgery led to the firm conclusion that the primary cause of the chronic, disabling low-back or herniated-disc syndrome was simply joint malfunction.

The chief causes of joint malformations were congenital changes, a surprising number of which were not demonstrable by roentgenograms, even by multiple views, including stereoscopic roentgenograms. Demonstration of four major transitions in the evolution of man explained why malformations are so frequent and so concentrated at the lumbosacral area. In 600 patients who were operated on by the authors' bone-bur arthodesing technique, it was demonstrated that when a strong stabilization of the facet joints was obtained, aches in the disc and joints were permanently eradicated.

Repair of Avulsion Injuries of the Posterior Cruciate Ligament. Col. John J. Brennan[3] presented an original surgical approach for repair of an avulsion fracture of the tibial attachment of the posterior cruciate ligament.

Instead of the popliteal approach, Colonel Brennan uses a small, anteromedial vertical parapatellar incision and a posteromedial incision. The posterior incision is the same as that usually employed for posterior approach to the meniscus or for drainage of the joint, as described by Henderson. Loose comminuted bone fragments are removed through the posterior incision. The medial semilunar cartilage is completely removed. This greatly increases the visibility in the posterior compartment of the knee. Two drill holes are made from the cortex of the tibia to the posterior bone defect of the tibia. Stainless-steel wire, passed through the drill holes, fixes the fragment and posterior cruciate ligament to its original attachment. Forward displacement of the tibia on the femur assures optimum tension of the anterior cruciate ligament under direct vision.

After operation, a toe-to-groin cast is applied in extension greater than 170 degrees. This position is deemed necessary to decrease the efficiency of the hamstring muscles. Immobilization is maintained for six weeks.

Surgical Treatment of the Hip in the Adult. Dr. H. H. Brindley[4], Dr. R. A. Murray, and Dr. W. A. Ross gave a historical review of the treatment of hip disease in the adult. It included

1. 919 18th Street, N.W., Washington 6, D. C.
2. Medical and Dental Building, Seattle 1, Washington.
3. William Beaumont General Hospital, El Paso, Texas.
4. Scott and White Clinic, Temple, Texas.

various surgical procedures in the treatment of fracture, non-union of fracture, osteo-arthritis, infection, and old, paralytic dislocation.

Autoradiograms of the Femoral Head. Dr. Rocco A. Calandruccio [5] obtained femoral-head specimens from patients who had prostheses inserted for avascular necrosis of the femoral head, non-union of fracture of the neck of the femur, recent fracture of the neck of the femur, and arthritis of the hip joint. Tracer doses of radioactive phosphorus were injected one hour before removal of the specimen. The specimens were bisected through the ligamentum teres in a coronal plane, and autoradiograms were made of the entire specimen.

In addition to the presentation of roentgenograms, gross specimens, microscopic sections, and autoradiograms of patients from each category, Dr. Calandruccio showed autoradiograms of the femoral head of both the mature and the immature dog. In the mature dog there is a sharp demarcation of the uptake of P^{32} at the old epiphyseal line; in the immature dog there is high concentration of P^{32} in the area of provisional calcification. When the blood supply was surgically impaired, autoradiograms revealed that one hour after injection there was no uptake of P^{32} in the femoral head.

The following observations were made from the clinical material: (1) There is little or no P^{32} uptake in non-viable bone one hour after intravenous injection of P^{32}; (2) There is an increased uptake of P^{32} in newly formed bone as compared with the remainder of the femoral head and neck; (3) The autoradiograms of the specimens from non-unions and from recent fractures outline the viable and non-viable bone areas, areas that are not often readily appreciated in the gross and microscopic sections; (4) There is an increased uptake of P^{32} in the superior portion of the femoral head of arthritic patients; (5) There is a higher concentration of P^{32} in newly formed bone; and (6) In an area of bone, such as the head of the femur, which is known to have normally an uptake of P^{32} one hour after injection, the lack of P^{32} uptake suggests a disturbance of the nutritional status or viability of the tissue. For if radioactive phosphorus (P^{32}) is unable to reach and exchange with the P^{31} of this tissue, neither, presumably, can there be an exchange of other ions and substances necessary for metabolic activity.

Experiences with Polyurethane Foam. Dr. Robert B. Clark [6], Dr. William M. Davis, and Dr. Walter A. Hoyt, Jr., presented the results of accumulated experimental data of the physical properties of polyurethane foam. Power mixing was far superior to hand mixing; the tensile strength of the material was increased two and one-half times when the material was power-mixed. The authors said that even when it was mixed at 80 degrees Fahrenheit, the temperature of the material rose as high as 165 degrees Fahrenheit, and that temperatures this high were probably deleterious to human tissue. It was demonstrated that the pouring technique was inaccurate and limiting, whereas extrusion with a caulking gun was more advantageous and offered a wider usage of the material. Polyurethane foam is not a glue and its adhesive or bonding strength to bone is less than 100 pounds per square inch. Because even in adequate cross-section the strength of the material was insufficient to withstand the stresses placed upon it, this material is best used as a supplement to metal. The physical properties presented definite problems of accuracy of control still to be worked out. In addition, the biological acceptability of polyurethane foam is uncertain at this time, necessitating continuing investigation before its widespread use is undertaken.

Spine Studies: Part I Mechanics. Dr. John R. Cobb [7] and Dr. Konstantin P. Veliskakis exhibited the first part of a series of studies of the spine, started in 1935.

In Section A the mechanics of a segmented column were demonstrated, with drawings and legends emphasizing the importance of angulation as a factor in causing the greatest deviation of the atlas from the central axis and base of the spine. The deviation is always in the direction of the angulation. Multiple adjacent angulations cause greater displacement of the atlas and segments in that direction and result, geometrically, in a curve.

Section B, on the mechanics of the spinal column, demonstrated some of its differences from a simple column, there being normally three areas of adjacent vertebral angulation or curves in the anteroposterior plane.

Section C, on the roentgenogram, showed by a plane shadow of a column of solid segments the four cardinal signs of structural changes, and a method of measurement of wedging, angulation, rotation, and position changes, using a part of an involved vertebra as a unit of measurement, the total angulation being measured in degrees as usual.

Committee for the Advancement of Automobile Safety. Prevention of Automobile Injuries. Dr. Murray E. Gibbens [8], *Chairman*. The Committee again presented an exhibit on automobile safety and again stressed the value of safety belts for all passengers. Photographs

5. Campbell Clinic, 869 Madison Avenue, Memphis 3, Tennessee.
6. City Hospital, Akron 9, Ohio.
7. 333 East 43rd Street, New York 17, N. Y.
8. Veterans Administration Hospital, Denver 20, Colorado.

were shown of a survivor and his car, both involved in a severe racetrack accident; the seat belt and roll-bar were credited as having saved the life of the driver.

Another factor of special interest to orthopaedic surgeons is the possibility that poor posture, owing to the position of the seats in modern cars, may contribute to somnolence of the driver. By way of contrast, the seats in buses and trucks are quite good in this respect. This may be an important factor in the good safety record of bus and truck drivers.

Because all drivers are also part-time pedestrians, they should be interested in the removal of pointed objects and sharp edges from the front ends of all automobiles.

The Committee reiterated the importance of good driver education, the use of safety seat belts, and better safety engineering of cars and highways.

Committee on Biomechanics. Specifications for Success. Dr. Jack Wickstrom [9], *Chairman*. The successful use of implants depends on proper material, precision design, careful manufacture, quality control, careful application, and adequate protection. The Committee discussed stress corrosion; transfer of dissimilar metals during application of a device; and the tissue reaction to chromium and nickel, as well as to iron salts, resulting from transfer of ions and metallic particles to surrounding tissues adjacent to implants. The effect of repeated accumulative stress on metals, producing failure by fatigue, was included in a graph illustrating the safe limits of metallic fatigue. Overloading reduced fatigue life abruptly.

Committee on Instructional Courses. Clinical Data-Cases for Instructional Course Dinner Program. Dr. Fred C. Reynolds [10], *Chairman*.

Committee on Pathology. Diagnostic Problems in Orthopaedic Surgery. Dr. Crawford J. Campbell [11], *Chairman*. Pathological lesions in the bones of persons forty-five years of age or older were illustrated to correlate history, clinical findings, roentgenograms, and pathology. The lesions included stem-cell leukemia of the pelvis; myeloma of the pelvis; tuberculosis of the knee; juxta-articular cyst of the knee; Paget's disease, with sarcoma of the femur; reticulum-cell sarcoma of the femur; hyperparathyroidism, with a large lytic lesion in the humerus; osteomyelitis of the spine; fibrosarcoma of the humerus; renal-cell carcinoma of the lower humerus; renal-cell carcinoma, metastatic to the lower humerus; carcinoma of the esophagus, metastatic to the cervical spine; and chondroma of the cervical spine.

Torticollis in Infants and Children. Dr. M. B. Coventry [12], Dr. L. E. Harris, and Dr. A. J. Bianco, Jr., discussed congenital muscular torticollis, from infancy to adulthood. The report was based primarily on findings at routine examination of infants and children in the Well-Child Clinic in Rochester, Minnesota.

A study of thirty-five newborn infants diagnosed as having tumors of the sternocleidomastoid muscle demonstrated that the tumor spontaneously regresses in an extremely large percentage of patients. This observation supported the authors' opinion that early treatment should be conservative (non-surgical). Asymmetry follows the appearance of the tumor, and also usually regresses spontaneously.

The authors presented the etiology, incidence, pathology, and differential diagnosis of torticollis, and described the surgical treatment of well developed wryneck in children and adults, together with the results that one may expect.

M.I.T. Adjustable Brace. Dr. Thomas L. DeLorme [13], Dr. F. W. Bora, Jr., and Dr. E. J. Morrissey, Jr.

Systemic Diseases as Manifested in Roentgenograms of the Hands and Wrists. Dr. Anthony F. DePalma [14], Dr. Irvin I. Kricheff, Dr. Thurman Gillespy, and Dr. James M. Hunter exhibited forty-two roentgenograms of the hands and wrist to demonstrate the diagnostic roentgenographic changes of thirty-nine different systemic diseases. Pertinent clinical findings were given with each case discussed. The diagnosis, differential diagnosis, and discussion of the roentgenograms were presented in a manner that allowed the viewer to test his diagnostic acumen before looking at the answer.

Absolute Peripheral Fixation in Hip Fractures. Dr. William Minor Deyerle [15] described a new plate, which acts as a guide for peripheral insertion of multiple threaded pins deep into the cortex of the head. The plate maintains a preselected angle of these pins as they go through

9. 1430 Tulane Avenue, New Orleans 12, Louisiana.
10. 4960 Audubon Avenue, St. Louis 10, Missouri.
11. 721 Madison Avenue, Albany 8, New York
12. Mayo Clinic, Rochester, Minnesota.
13. 275 Charles Street, Boston 14, Massachusetts.
14. 248 South 21st Street, Philadelphia 3, Pennsylvania.
15. 2222 Monument Avenue, Richmond 20, Virginia.

the shaft of the femur. The pins are threaded in the head portion to give fixation and to avoid any rotation. In the event of any shortening they can still slide both in the shaft of the femur and in the plate itself to allow for continuous contact compression.

The principle involved is that the peripherally placed pins, one-eighth of an inch in diameter, spread peripherally in the head, have a stronger grip on a larger number of stronger (cortical) trabeculae. The central pin fixation or tri-flanged nail has a grip on a smaller number of trabeculae of relatively weaker trabeculae because the pins or nails are centrally placed and the trabeculae are partially cancellous. This places a greater strain on the same trabeculae because resistance to rotation at the center is much less efficient than resistance to rotation peripherally placed. If there is no motion at the fracture site the head has a maximum opportunity for revascularization because the blood vessels attempting to go across the fracture site are not injured or destroyed. Also, early weight-bearing stimulates early union. When the author's procedure is used the fracture line receives maximum protection; there is no motion and the slidability of the apparatus allows for continuous contact compression.

The fixation technique requires a minimum of five pins for a neck fracture and eight for an intertrochanteric fracture. It has been used in forty-six fractures. Follow-up of from one to three years of twenty-seven femoral-neck fractures showed no non-unions, and in only one was there avascular necrosis.

The test for absolute fixation is the superimposing of the end-result roentgenograms upon the immediate postreduction roentgenograms. If these will superimpose this is proof that there has been no motion at the fracture site and no shortening. Any shortening of the neck of the femur is the result of motion at the fracture site and is not the normal healing process of the fracture.

Rib Osteo-Periosteal Grafts for Fractures of Both Bones of the Forearm. Comdr. James R. Dineen [16] and Lt. Richard B. Gresham used a well known common fracture problem as a practical application to point out the high osteogenetic function of osteoperiosteal grafts as the singular factor in the relatively short healing time (from ten to twelve weeks) for fresh fractures of both bones of the forearm. The authors described four representative cases of the twelve grafts they performed during the past three and one-half years, using roentgenograms and color photographs to demonstrate the end results.

A unique feature of the exhibit was a model of the donor site of the osteoperiosteal graft—the seventh, eighth, and ninth ribs at the mid-axillary line. A continuous slide showed the operative procedure itself. In addition, there was a practical demonstration in which beef bone, mallet, and gouge were used.

Bone and Joint Changes Following Burns. Dr. E. Burke Evans [17] and Dr. J. R. Smith presented a classification of skeletal changes, based on a study of the roentgenograms of twenty-five severely burned patients with alterations in addition to osteoporosis and of selected patients with osteoporosis alone. The alterations included osteoporosis, periosteal new-bone formation, irregular ossification, tangential sequestration, pericapsular calcification, osteophyte formation, heterotopic ossification, articular destruction, and ankylosis. These alterations were demonstrated by roentgenograms of representative cases for each of which there was accompanying text regarding incidence, distribution, time of onset, and possible causative factors.

In a review of surgical experience, it was emphasized that no corrective surgical procedure should be undertaken until the scar over the operative site was mature and soft and there was no active scar or granulating surface in other areas.

Classification of Cervical Spine Injuries. Dr. H. Francis Forsyth [18] and Dr. Joseph Whitley classified cervical-spine injuries according to the mechanism of injury. Serial diagrams that showed the relative position of the head and the cervical vertebrae in various stages in the production of each type of fracture were followed by roentgenograms that demonstrated the type of injury. The authors analyzed 159 cases of serious injury to the cervical spine and found that each characteristic type of injury is caused by a certain type of force acting in a certain direction, producing a result that is highly predictable.

The primary forces involved are flexion and extension, depending on whether the force is directed toward the back of the head or the front. These forces may be modified by having a downward component referred to as compression, or an upward direction referred to as without compression. If a direct force is applied in the mid-line the resulting injury will be symmetrical or bilateral, but if the force is tangential or is applied to one side of the head, the resulting injury will be of a rotatory or unilateral nature. Occasionally, a pure compression force is applied by a fall directly on the top of the head, with no element of flexion or extension. This results in a bursting fracture, which usually involves the atlas.

The most significant fact in the analysis is that extension forces are now known to cause at least as many of the demonstrable injuries of the cervical spine as the flexion forces. This is contrary

16. United States Naval Hospital, Camp Lejeune, North Carolina.
17. The University of Texas — Medical Branch, Galveston, Texas.
18. Bowman Gray School of Medicine, Winston-Salem, North Carolina.

to any previous thinking on the matter.

The simple and practical classification, which covers almost every conceivable type of injury to the cervical spine, is as follows:

1. Flexion (unilateral) (bilateral)
   - Without compression (anterior dislocation);
   - With compression (fracture or fracture dislocation);
   - Hyperflexion.
2. Extension (unilateral) (bilateral)
   - Without compression (posterior dislocation);
   - With compression (fracture or fracture-dislocation).
3. Combined flexion and extension.
4. Compression (bursting fracture).
5. Direct trauma.

Modern Methods for Metallic Repair of the Upper End of the Femur. Dr. W. Stanford Foultz [19] exhibited twenty-four life-size, clear-plastic models, illuminated from below by transmitted light to bring out the detail of the upper end of the femur. Transparent captions, giving a complete description, were placed below each model. The models demonstrated various fractures in the region and the appropriate appliances for repair. In addition, one model showed the internal anatomy of the base of the femoral neck and had embedded in its substance a portion of bone dissected from the human femur. This particular model demonstrated the calcar femorale as a dense vertical plate of cancellous bone in the lower posteromedial part of the neck and related its importance to proper placement of fixation devices.

Several models demonstrated complications encountered in the treatment of fractures in the upper part of the femur. One model showed how a comminuted peritrochanteric fracture can collapse if the medial buttress of the proximal major fragment and the lateral buttress of the distal fragment are fractured. The Neufeld nail used in this particular model had penetrated the head, with medial shift of the shaft. Another model showed a guide pin buckled on itself as the cannulated nail passing over it had become bound on the pin as it was driven in. A Smith-Petersen nail was shown in one model to have produced distraction and loss of reduction of femoral-neck fracture when the nail had failed to pierce the head. Another model showed that because of the triangular cross section of the femoral neck, a Smith-Petersen nail may lie outside the neck in its lower portion and still appear on both anteroposterior and lateral roentgenograms to be within the substance of the bone. The captions indicated how these complications can be avoided.

Other models, which demonstrated the use of metallic appliances in various conditions, were as follows: Cannulated Smith-Petersen nail for fracture of the femoral neck; Jewett appliance for peritrochanteric fracture; extra-long Jewett appliance for subtrochanteric fracture; Neufeld appliance for intertrochanteric fracture; clover-leaf nail for medullary fixation of subtrochanteric fracture; Moe plate for intertrochanteric fracture; Thornton plate and nail combination for intertrochanteric fracture; McLaughlin nail plate combination for intertrochanteric fracture; Knowles' pins for slipped capital femoral epiphysis; Pugh hip nail for femoral-neck fracture; Badgley nail-plate combination for femoral-neck fracture; Massie sliding nail for femoral-neck fracture; "Ken" nail for femoral-neck fracture; Staples osteotomy nail plate for non-union of femoral-neck fracture; Blount osteotomy blade plate for non-union of femoral-neck fracture; Naden-Reith prosthesis for femoral head; F. R. Thompson prosthesis; and Lorenzo screw for femoral-neck fracture.

The Skeletal Changes Common to Syringomyelia, Diastematomyelia, and Myelomeningocele Suggest a Common Origin. Dr. W. James Gardner [20] and Dr. John S. Collis said that the central nervous system originates as the embryonal neural groove which, by the fifth week, has closed to form the neural tube. The lumen of the neural tube constitutes the primitive ventricles and central canal of the cord. At the sixth week, the choroid plexus begins to secrete fluid into the closed tube, causing it to dilate. A certain degree of hydrocephalus and hydromyelia, therefore, is physiological in embryonal life. This distention normally becomes arrested as the foramina of the fourth ventricle develop. The shape of the surrounding vertebrae is determined by the size and shape of the developing spinal cord.

Identical skeletal anomalies are encountered (albeit with decreasing frequency and severity) in the infant with myelomeningocele, the adolescent with diastematomyelia, and the adult with syringomelia. They are spina bifida posterior, spina bifida anterior (bilateral hemivertebrae), fused

19. 115 East Hermosa Street, Santa Maria, California.
20. Cleveland Clinic, 2020 East 93rd Street, Cleveland 6, Ohio.

vertebrae, dilated vertebral canal, kyphoscoliosis, rib deformities, foot deformities, and enlargement of the skull.

If the development of the outlets of the fourth ventricle does not keep pace with the output of the choroid plexus, a pathological degree of hydrocephalus and hydromyelia will occur. This overdistention of the neural tube will distort and displace the nearby sclerotomes, resulting in distorted bones.

If the hydromyelia is mild, the infant appears normal but symptoms of syringomyelia will develop in adulthood.

If the overdistention is more severe, the spinal cord may split in the sagittal plane (diastematomyelia) and symptoms will appear in adolescence.

If still more severe, the overdistention may result in external rupture (myeloschisis) that will progress to myelomeningocele by the time of birth.

In its most severe form, in addition to external rupture, internal rupture into the primitive gut may occur, resulting in anterior as well as posterior spina bifida (bilateral hemivertebrae) with a divided spine and cord surrounding a fistula of the gut that opens onto the back. Infants with the anomaly are usually stillborn.

The similarity of the skeletal and spinal-cord anomalies in these states support this hydromyelic theory of their origin.

Chondrosarcoma. Dr. Raphael R. Goldenberg [21], Dr. Leon Root, and Dr. Philip Cohen presented an exhibit of proved selected cases of chondrosarcoma. Each case was used to illustrate an interesting pathological or clinical feature of chondrosarcoma. Two instances of the tumor arising in soft tissue were included in the exhibit. The authors described the essential methods of establishing the diagnoses. Follow-up reports were available for each case.

Lower Extremity Amputation Prostheses—Special Problems. Dr. J. Leonard Goldner [22], Dr. Frank W. Clippinger, and Mr. Bert R. Titus, in discussing lower-extremity prostheses, emphasized the relationship between the patient and the clinic team, the physician, the occupational and physical therapist, the prosthetist, and the agency, as well as the patient's family and employer.

When a prosthesis is fitted in the lower extremity of adults and children there are certain special problems that can only be handled by adaptation or modification of the usual conventional prosthesis. A short history of these particular problems was presented by the authors, with enlarged, mounted photographs illustrating the preoperative or prefitting condition of the patient and the prosthesis used to aid in solving the problem. The problems discussed were as follows:

1. A nineteen-year-old boy with gigantism of both feet. One foot was amputated and a Symes stump formed; the other was trimmed to allow fitting with a size-thirteen shoe. This was an exceedingly satisfactory way to handle the problem; the boy was able to wear leather shoes for the first time in his life.

2. A young man who had osteomyelitis of the femur resulting in fourteen inches of shortening was fitted with a plastic prosthesis that utilized the equinus position of the foot. A regular shoe was attached to a platform in the prosthesis. This short prosthesis, anchored to the bowed calf, was superior in this instance to a high thigh amputation followed by a standard prosthesis.

3. A child with congenital absence of the femur with a good foot and ankle joint was fitted with a prosthesis that utilized her ankle joint at the same level as the knee joint of the prosthesis and obviated the necessity of extensive reconstruction of her foot in order to provide a limb. The foot sits on a platform and projects about six inches in front of the prosthesis. If this bothers the patient when she gets older, it can be trimmed down to a mid-tarsal amputation, leaving the heel for in-bearing in the prosthesis.

4. A twelve-month-old child with congenital deformity of one lower extremity had a below-the-knee amputation of the upper third of the leg and flexion deformity of the knee. This patient was fitted with a flexed knee socket, held in place by close fit or modified suction, and a light strap around the waist. A SACH foot was utilized with considerable success.

5. A patient with heart disease and bilateral above-the-knee amputations wanted to be able to get around in his own home. He was fitted with bucket-type prostheses only a few inches longer than his stumps, on the bottom of which were large pachyderm rubber pads that allowed him to maintain balance and move around the house and on the street with ease, using crutches if he so desired. This man could have not handled conventional prostheses and, ordinarily, would have been confined to a wheel chair.

6. A hemiplegic with above-the-knee amputation on the side of the hemiplegia. His muscle strength was not sufficient to warrant regular prosthesis, but his general condition allowed him to be up and about. A modified knee lock of a German type was utilized to allow the patient to walk with a stiff knee, but to flex it when he sat. This prosthesis was as light as the usual pylon and more acceptable to the patient.

7. A patient with hip disarticulation for bone tumor needed a Canadian-type hip disarticulation prosthesis. The pelvic socket was made of plastic.

21. 588 East 27th Street, Paterson 4, New Jersey.
22. Duke University Medical Center, Durham, North Carolina.

The adjustable limb for both upper and lower extremities was illustrated and emphasis was placed on the fact that it has aided the limb maker considerably in getting an accurate fit of both the above-the-knee and the below-the-knee prostheses, particularly in those patients who might have slight abduction and flexion contracture of the hip or rotary deformity around the knee joint with variations in varus and valgus, which are not obvious until the patient is actually observed walking and attempting to maintain balance. The adjustable limb localized accurately the height of the knee joint, the rotation of the leg, and the inward and outward angulation of the leg in relation to the thigh. Most patients are now placed on the adjustable limb when the preliminary fitting of the socket is done and are required to walk on the adjustable limb for two or three days before the socket is completed and before the leg portion is attached to the prosthesis. Currently being used are a child's size below-the-knee adjustable limb and adult's size below-the-knee and above-the-knee adjustable limbs.

Other illustrations included the knee disarticulation prosthesis with a leather socket and a prosthesis with quadrilateral suction socket and outside knee joints for a very long above-the-knee stump. Also shown was a Muley-type below-the-knee limb, which is held in place by a suction device below the knee, with only a small holding strap above the knee. Emphasis is now being placed on construction of the below-the-knee prosthesis without thigh lacer.

A special prosthesis is used for the patient who has had poliomyelitis followed by amputation for some other reason and who now has a high above-the-knee amputation with flexion and abduction contractures of the hip, which for some reason cannot be corrected surgically. Special fitting of the socket with built-in abduction and flexion can be done to make a satisfactory functional, usable limb.

The "Unsolved" Fracture: Femoral-Neck Fractures, a Continuing Challenge. Dr. Bernard M. Halbstein[23] and Dr. Enrique T. Pardon depicted, with plaster-of-Paris models, many of the problems accompanying femoral-neck fractures. No single method of treatment is considered rational or reliable because these fractures all present different problems. Many variables, such as the age of the patient, mental and physical condition, condition of the bone, type of fracture, circulation of the femoral head, technical errors, time of treatment, or postoperative complications, influence the eventual outcome. Therefore, no two cases can possible run parallel and management must be individualized. The most important inconstancy may by the judgment and ability of the surgeon.

The authors discussed the common types of hip fractures, the circulation of the hip, the Pauwels' lines, and the treatment of fresh fractures and the reasons for failure of internal fixation, along with the indications for primary hip prostheses and the methods of reconstruction of ununited hip fractures.

The callenge of the "unsolved" fracture will be met by the accumulated experience of many observers, a better understanding of the problem, and more accurate indications. Furthermore, training of more and better orthopaedic surgeons, improvement in metals and material design, and earlier diagnosis of avascular necrosis by radioactive isotopes will aid considerably in increasing the percentage of successful treatment. The recommended treatment of fresh fractures is by Smith-Petersen nailing, providing the reduction is stable and in valgus position. An unstable reduction should be carefully analyzed and treated by immediate subtrochanteric osteotomy, open reduction, or insertion of a prosthesis.

Myelography with Water Soluble Media. Dr. J. Paul Harvey, Jr.[24], and Dr. R. H. Freiberger said that myelography with water-soluble contrast media was developed by Lindstrom and Arnel in the early 1930's. Lumbar myelograms have been done routinely by this method in Sweden since the mid-1940's and are now done routinely in some other European countries.

The authors demonstrated a method of giving a low spinal anesthetic, and, ten minutes later, an injection of ten cubic centimeters of the contrast substance, an iodine compound, sodium monoiodomethane sulphonate. Roentgenograms of three patients with negative myelograms and six patients with positive myelograms showed disc protrusion, proved by subsequent operation. Results of forty-two of these myelographic studies were listed, as well as the amount of anesthetic and the anesthetic level reached. Side effects such as back pain (seven instances), leg pain (six instances), rectal pain (three instances), nausea (eleven instances), and meningismus (one instance) were listed. There were only three patients who had minor complaints beyond twenty-four hours, and none beyond seven days.

The advantages of the method described are: (1) Increased accuracy of interpretation because the low viscosity (similar to spinal fluid) allows the arachnoid root sleeves to fill out completely and the lower contrast permits visualization of nerve roots; (2) Complete absorption of the contrast substance: no withdrawal is required and no residue remains to cause foreign-body reaction; and (3) Ease of examination: dark adaptation and fluoroscopy are not necessary.

The disadvantages are: (1) spinal anesthesia is necessary to prevent severe pain; (2) possible permanent neurological complications (three in 760 cases reported recently, but there is question

23. 263 Bath Avenue, Long Branch, New Jersey.
24. 535 East 70th Street, New York 21, N. Y.

of change in techniques); (3) contrast substance must be kept in the anesthetized area, thus precluding examination above the lumbar area; and (4) roentgenographic technique must be perfect in the initial examination. Rapid absorption makes re-examination nearly impossible.

Torticollis. Dr. Fred Herzer[25] and Dr. Lewis Cozen reported on follow-up examinations of thirty-five children with torticollis. A number of the patients were seen many years after treatment ceased. The operatively treated patients had less deformity than those treated conservatively. Conservative treatment consisted in stretching exercises by the physical therapist and by the parents.

Surgical excision of the tumor in the sternomastoid muscle was demonstrated. Incision in the supraclavicular and inframastoid regions was advocated for the severe deformity.

The authors showed photographs made before and after treatment which pointed out that the results of treatment by both conservative and surgical methods were good.

The Clinical Results of 2,000 Freeze-Dried Bone Homografts. Capt. George W. Hyatt[26], Lt. Comdr. M. C. Wilber, and Capt. J. E. Cheffey.

Stereography in Teaching Orthopaedic Surgical Approaches. Dr. John J. Joyce, III[27], and Dr. Michael Harty said that by stereographic color transparencies, surgical approaches to the bones and joints can be realistically demonstrated. The exposures can be seen with a stereoscopic viewer by the individual or projected to a group for teaching. The authors plan to produce a manual of three-dimensional surgical approaches. They believe that this teaching medium is both realistic and forceful.

A Demonstration of the Blood Supply of the Tibia. Dr. Patrick J. Kelly[28], Dr. George E. Nelson, Jr., Dr. Lowell F. A. Peterson, Dr. Joseph M. Janes, and Arthur H. Bulbulian, D.D.S., conceded that three main groups of vessels contribute to the blood supply of long bones. The basic divisions are the epiphyseal-metaphyseal, the nutrient, and the periosteal vessels. The first division is sometimes further subdivided into epiphyseal and metaphyseal groups by some investigators, especially in the immature animal.

The authors elucidated three basic points: (1) the relative importance of the periosteal vessels, (2) the architecture of the venous system, and (3) the type of vessels in the Haversian canals.

Fourteen human adult tibiae were studied. These were obtained from limbs amputated for malignant disease, without evidence of occlusive vascular disease. Immediately after amputation the limbs were perfused with Ringer's solution and then injected with an India ink-gelatin solution or barium sulphate-gelatin solution (micropaque). The limbs were stored overnight in a refrigerator to allow the injection mass to solidify in the vascular system.

Next, the legs were dissected grossly to find the origin of the extra-osseous blood supply of the tibia. Each tibia was then decalcified in a 15 per cent solution of formic acid and serial sections were cut, cleared by the Spalteholz technique, and studied under the dissection microscope. Selected sections were then embedded in celloidin and cut in thicknesses varying from twelve to sixty micra. These were stained with hematoxylin and eosin to allow study of the finer microscopic details. In addition, microangiograms were made of the sections of tibia injected with the radiopaque medium.

The epiphyseal-metaphyseal regions are supplied by arteries entering on all sides. These arteries have accompanying veins which enter with the arteries. These vessels have a distribution to the epiphyseal-metaphyseal region that looks much like the spokes of a wheel when this region is viewed in cross section.

The nutrient artery, a branch of the posterior tibial artery, is the main source of blood supply to the diaphysis. The nutrient artery, soon after entering the medullary cavity, divides into three ascending branches and one descending branch. The descending branch remains as a single major vessel for some distance before branching. The ascending and descending branches give off radial arterial branches which enter the cortex and further subdivide to supply the capillaries of the Haversian canals.

The periosteum is supplied by branches of the anterior tibial artery. Only small capillaries enter the cortex from the periosteum. In addition, periosteal vessels are incorporated in Haversian systems formed from the periosteum.

The venous drainage of the diaphysis is largely toward the endosteal surface through veins that accompany the branches of the nutrient artery. In addition, venous channels, thin-walled and somewhat larger in diameter than the periosteal capillaries just described, seem to drain venous blood toward the periosteal surface.

Haversian canals contain from one to four vessels, the majority having two or three vessels. These are usually capillaries, and only occasionally can arterioles or venules be seen in Haversian canals.

25. White Memorial Hospital, Los Angeles 33, California.
26. United States Naval Medical School, Bethesda, Maryland.
27. 5908 Greene Street, Philadelphia 44, Pennsylvania.
28. Mayo Clinic and Mayo Foundation, Rochester, Minnesota.

The over-all pattern of the tibial blood supply was depicted by (1) a semidiagrammatic model of the tibia, enlarged two times; (2) six transparent photographs of cleared sections (× 4) obtained from representative levels; and (3) six photomicrographs of microscopic sections to illustrate finer details of periosteal and cortical circulation.

Certain Sensory Defects in Children with Cerebral Palsy: Importance to Treatment. Dr. William E. Kenney [29], Frederick T. Pansera, R.P.T., and Laura C. Verry, O.T.R., pointed out that cerebral palsy has been regarded largely as a locomotor disturbance, and sensory defects have received little attention. Important sensory disturbances exist in approximately 70 per cent of the patients. In the main, the difficulties are in stereognosis, two-point discrimination, and sharp and dull perception, although abnormal position sense and agnosia of parts are also factors. Furthermore, the problem involves the feet as well as the hands.

The authors emphasized the role that such sensory defects play in self-care, such as eating and dressing, as well as in gait-training and didactic teaching. The orthopaedist should be as well aware of the sensory losses of an extremity as he is of the locomotor problem before undertaking surgery. Even when a locomotor imbalance is corrected surgically, little practical benefit will accrue because the patient will not use the extremity if an appreciable sensory loss exists.

The Importance of Drug Administration in Orthopaedic Surgery. Dr. Otto C. Kestler [30] said common experience has shown that many of painful musculoskeletal disorders seen in orthopaedic practice are not completely relieved by surgery, corrective devices, physiotherapy, or other standard orthopaedic procedures. It is not well recognized, however, that certain drugs, now available, can replace or complement such measures and produce a gratifying increase in successful results. All too often only salicylate therapy is consistently employed, whereas more specific and effective agents are seldom used.

The author discussed, briefly, phenylbutazone, adrenocorticosteroids, and muscle-relaxant drugs.

Fate of Lead in Synovial Fluid. Dr. Morton H. Leonard [31], Dr. Louis W. Breck, and Dr. Zigmund W. Kosicki described what happens when a bullet protrudes into a joint and is bathed by synovial fluid. The clinical findings in three such situations were reported.

Lead bullets dissolve in synovial fluid and the particles of lead are deposited in the synovial membrane. Plumbism may result, but chronic synovitis and arthritis do result. Roentgenograms of such joints have an appearance similar to those into which radiopaque material has been injected to carry out contrast studies. At surgery the synovial membrane is gray. The resultant irritation causes loss of joint cartilage. Microscopically, there is deposition of lead in intracellular and extracellular spaces with chronic synovitis.

Traumatic Affections of the Shoulder. Dr. Eugene E. Lipow [32] and Dr. Charles S. Wise designed their exhibit to present the gross physiopathology of traumatic affections of the shoulder.

Because the shoulder joint possesses less stability and mechanical protection than any other large joint of the body and gravity produces a shearing strain rather than a stabilizing effect when the shoulder joint is injured, there is more involvement with muscles and tendons than when a weight-bearing joint is injured.

Conservative measures were stressed in the treatment of musculoskeletal, nerve, and tendon damage. However, the authors did discuss surgical repair of such damage, as well as of avulsed fractures, and torn or incised soft tissue.

The authors showed skeletal fixation *in situ* of the following devices: a Vitallium rim for fractures of the glenoid; a new blade plate for fixation of the humeral head, on multiple fractures of the shaft; intramedullary fixation in fractures of the clavicle; the Bosworth screw for acromioclavicular separation; the Steinmann pin to stabilize the head of the shaft in fractures of the surgical neck, which are difficult to maintain in reduction; and an intramedullary prosthesis for the humeral head, used for soft-tissue repairs in tears of the rotator cuff and for recurrent dislocation of the shoulder.

Injection for bicipital tendinitis, calcareous tendinitis, and adhesive capsulitis, was also discussed, along with the value of well directed and supervised physiotherapy and active exercise for proper rehabilitation.

Osteo-Onychodysplasia. Dr. Willard H. Love [33], Dr. Leonard F. Bush, and Dr. David D. Beiler demonstrated, with roentgenograms and photographs, the characteristic deformities encountered in osteo-onychodysplasia. The principal deformities involve typical dystrophic nails,

29. 218 Calvin Street, Fall River, Massachusetts.
30. 140 East 54th Street, New York 22, N. Y.
31. 520 Montana Avenue, El Paso, Texas.
32. 1150 Connecticut Avenue, N.W., Washington 6, D. C.
33. The George F. Geisinger Memorial Hospital, Danville, Pennsylvania.

hypoplastic or rudimentary patellae, and prominent medial condyles. Deformities of the elbow joint include a small and deformed radial head, which is usually subluxated or dislocated posteriorly. Another characteristic of the syndrome is the presence of iliac horns, palpable over the posterior iliac region and quite apparent on roentgenograms. Osteo-onychodysplasia (Turner's syndrome) is an inherited familial disease characterized by the deformities described.

Chemical Osteosynthesis—A New Method of Treatment of Fractures and Diseased Bone with a Polyurethane Polymer. Dr. Michael P. Mandarino [34], Capt. Joseph E. Salvatore, and Dr. Thomas L. Jones described a new method for treating fractures and diseased bone.

The description included the materials used, the preparation and physical properties of ostamer, and a report of animal studies and clinical cases. The mechanism of healing after implantation of ostamer was illustrated by photomicrographs.

Clinical experience up to September 1, 1959, involved a total of 308 cases. There were forty (12.9 per cent) unsatisfactory results. These were due largely to: the inlay graft being too short; inadequate mixing of ostamer; mixing ostamer too long; inadequate hemostasis; and preoperative osteomyelitis.

Photomicrographs made twenty-four hours after implantation demonstrated a lack of toxic diffusible material from ostamer. Further photomicrographs of the same tissue culture, made ten days after implantation, showed that the HeLa cell sheet had completely surrounded the ostamer fragment and had grown over sections of it. One photomicrograph showed ostamer after implantation in the tibia of a dog. The low-power section demonstrated a mosaic of ostamer and osteoblastic proliferation throughout, in addition to phagocytic activity.

Femoral Shortening. Dr. Leslie C. Meyer [35].

Development of Anomalies in Man: Iliopsoatic Syndromes. Dr. Arthur A. Michele [36] pointed out that only man achieved the erect posture in the anthropological progression from early primate and Neanderthal. To achieve this unique posture of lumbar lordosis a necessary adaptive elongation of the iliopsoas must take place.

If a person attempts to stand erect and there has been failure of the necessary, coincidental iliopsoatic lengthening during his vertical growth, a powerful intrinsic force of from 300 to 600 pounds per square inch is brought into play. Force of this magnitude is engendered by the site of attachment of the iliopsoas off the transverse processes and lateral bodies, with direction anteriorly over the brim of the pelvis to the lesser trochanter, which is posterior to the line of gravity in a 90-degree axially rotated femur.

The kinesiological function of the iliopsoas is, therefore, primarily that of an external rotator, then a flexor and adductor, and finally, as a cephalad projector of the head from the acetabulum. Acting from below, it can produce lateral inclinatory rotatory excursions of the vertebrae of the spine and, when acting bilaterally, lordosis of the lumbar spine.

The normal expression of iliopsoatic function is formation of the calcar femorale, anteversion of the femoral neck, and posture with lumbar curvature and pelvic tilt.

Abnormal function can be determined by a series of signs of re-enforced iliopsoatic tension. Expression of the external rotatory force is manifested by developmental hip dislocation, Legg-Calvé-Perthes disease, slipped capital epiphysis, torsion fracture of the femoral neck, avulsion fracture of the lesser trochanter, and degenerative disease of the hip joint. The vertical traction and rotation force expresses itself in Schmorl's nodes, scoliosis, spondylolysis or spondylolisthesis, osteochondrosis deformans juvenilis dorsi, isolated fracture of the transverse process (lumbar), and degenerative disease of the spine; in intestinal, urological, obstetrical, and gynecological manifestations; and in abnormal gait and deformities of the lower extremities.

Clinically, each of the iliopsoatic syndromes will demonstrate absence of or incomplete axial rotation of the lower extremity, psoatic gait, or spinal release attitudes and deformities in relation to the line of gravity. The re-enforced iliopsoatic tension signs are positive. Therapy is directed toward adequate elongation of the iliopsoas, through stretchings and exercises; rotational osteotomy; or transfer of the iliopsoas attachment to a position of stabilization, an anterolateral one below the greater trochanter.

The earlier the recognition and treatment—particularly before adaptive changes of the various structures have occurred—the more favorable the prognosis.

The Shackled Acetabular Replacement Prosthesis. Dr. Earl D. McBride [37] presented a report of six years' experience with an acetabular prosthesis, used for thirty-five patients. Unlike the conventional Smith-Petersen cup, the prosthesis is designed to replace the acetabulum completely, thereby eliminating weight-bearing within the acetabulum. A rim, one-fourth of an inch wide, extends from the edge of the cup, which rests on the outer borders of the acetabulum. There

34. 210 North 15th Street, Philadelphia 2, Pennsylvania.
35. 9 Medical Court, Greenville, South Carolina.
36. 166 Clinton Street, Brooklyn 1, New York.
37. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.

are four thin fins extending around the convex outer surface of the cup so that when the prosthesis is driven into the acetabulum it is firmly fixed into position and cannot rotate, but can move sufficiently to adjust to the best position of weight-bearing. This produces a shackled effect in the artificial socket rather than firm fixation, such as obtained with screws. The head must be trimmed and shaped to fit the inner cup of the prosthesis. No reaming of the acetabulum is required.

This prosthesis has been used in severe deformities of the head of the femur, such as mushroom deformity; osteo-arthritic ankylosis; aseptic necrosis of the hip; and fracture-dislocation of the hip, with absence of bone where the posterior rim of the acetabulum was absorbed. In the patients with aseptic necrosis it has given better results than a hip-joint prosthesis. One great advantage of this acetabular prosthesis is that the patient has much less muscle spasm and postoperative pain than would be present with the standard cup arthroplasty.

The Vascular Pattern of Bones of the Extremities of Man. Dr. John G. Nork [38], Dr. James B. Wray, Dr. William B. Jones, and Dr. Joseph E. Markee outlined the total vascular pattern of bones of extremities obtained from freshly amputated human specimens. Thirteen specimens were utilized in the study, all of which were amputated for reasons other than vascular insufficiency. Immediately after amputation, the entire vascular bed of the extremity was flushed with warm normal saline solution and permitted to remain at rest for a period of from twelve to twenty-four hours. Methyl methacrylate with its catalyst and promoter was then injected by way of the major arteries of the part until complete filling of the entire vascular bed was obtained. This was noted by a return of the plastic through the major venous channels. Specimens for study were then prepared by digesting the entire extremity in a solution of potassium hydroxide, dissecting the soft tissue, and observing the vascular pattern of the bone structures. Some of the bones were then treated alternately with acid and alkali to remove the bone matrix and mineral, leaving a plastic mold for study.

Another method of study was performed by utilizing sections of previously injected undecalcified bone, after all of the soft tissue had been dissected away prior to any digesting techniques. The bone was fixed in methyl methacrylate and sections between thirty and forty micra thick were obtained. In this way a cross check of previous investigations was made. These preparations, therefore, permitted accurate visualization of the injected vessels and their relationship to the main arterial and venous channels, as well as relationship to the surrounding bone.

The major conclusions were that the arterial supply of bone is derived from four sources: (1) the nutrient vessel; (2) the metaphyseal vessel; (3) the epiphyseal vessel; and (4) the periosteal vessel, which anastomose both intra-and extra-osseously in the adolescent bone. In adult bones the metaphyseal and epiphyseal vessels merge to form one unit.

Venous drainage is accomplished by two major routes: (1) the large vessels draining from either end of a long bone, which we have termed metaphyseal-epiphyseal veins, in the adult; and (2) from the numerous small subcortical sinusoids of the diaphysis draining into periosteal veins. There is a striking independence of the arterial and venous systems within bone. Of the many thousands of Haversian systems studied, down to from thirty to seventy micra in diameter, there were no paired vessels. The only persistent occurrence of arteries and veins running as companions was noted to be present in the outer layer of periosteum.

Benign Soft-Tissue Tumors of the Hand. Dr. George S. Phalen [39], Dr. J. I. Kendrick, and Dr. L. J. McCormack reviewed 500 soft-tissue tumors of the hand seen at the Cleveland Clinic from 1948 to 1958. Kodachrome transparencies showed the appearance, the surgical specimens removed, the roentgenograms, and the photomicrographs of various tumors in the hand. The incidence of the various tumors as they occur in the hand, as well as the sites of occurrence, was also discussed.

The first panel of transparencies depicted swellings in the hand associated with systemic disease, including gout, xanthomatosis, and rheumatoid nodules. The second panel showed tumors arising from joints and tendons, including giant-cell tumors of tendon sheaths (benign synovioma) and ganglia. The third panel described tumors of blood vessels and nerves, including hemangioma, glomus tumor, neuroma, and neurilemmoma. The fourth panel illustrated connective-tissue tumors, including lipoma, fibroma, myxoma, and foreign-body granuloma.

Evaluation of a New Drug Effective in Cerebral Palsy. Dr. Winthrop M. Phelps [40] evaluated a new relaxant drug, W-712, given to more than eighty cerebral-palsied children, both in private practice and at the Children's Rehabilitation Institute, Reisterstown, Maryland. The drug has been found useful, particularly among the spastic and rigidity groups, in bringing about better relaxation of the extremities and more tolerance to bracing, thereby increasing the ability of the cerebral-palsied child to accept therapy. There were no adverse effects from the drug, and only occasional side effects of drowsiness and lethargy. The drug was evaluated primarily through the use of objective graphed recordings of responses to individual performance tests. This method,

38. 107 Indiana Circle, Travis Air Force Base, California.
39. Cleveland Clinic, 2020 East 93rd Street, Cleveland 6, Ohio.
40. 3038 St. Paul Street, Baltimore 18, Maryland.

which is useful not only in drug evaluation but also in charting the general progress of the cerebral-palsied patient, was described in detail.

Chemical Osteosynthesis. Dr. Irving Redler [41], Dr. G. Gernon Brown, and Dr. William V. Trekell used a polyurethane polymer, ostamer, in fifty-one orthopaedic procedures, and showed by drawings, color photographs, and sepia prints, the operative technique used, the results obtained, and the complications encountered.

The Ortho-Aide Splint. Lt. Robert W. Rogers and Dr. Marvin H. Meyers [42].

Surgical Masking *versus* Operative Infection. Dr. Charles Rombold [43] and Dr. William R. Miller conducted their experiment for two purposes: (1) to determine the efficiency of the usual masking techniques in preventing nasopharyngeal contamination of surgical fields, and (2) to devise a simple, efficient surgical mask.

Except for the variations in masking the same surgeon conducted each series of tests under identical conditions in an operating room readied for major surgical procedures. The operative field was simulated by a Petri dish culture on an operating table eighteen inches from the surgeon's face. The masks used were the conventional gauze masks supplied by the surgical supply firms. The surgeon talked constantly for the five minutes of each test. Five tests of each condition were made and the average number of colonies determined.

Under the following conditions the average numbers of colonies were:

Without a mask (control), 230; mouth only masked, eighty (60 per cent efficient); mouth and nose masked, thirty (87 per cent efficient); mouth and nose masked with second mask over mouth, fifteen (94 per cent efficient); and mouth and nose masked with a plastic sheet between the first and second masks over the mouth, two (99.8 per cent efficient).

It was concluded that expectoration into the operative field incident to the use of consonants in speech is diminished by heavily masking the mouth. A very simple, cheap, and highly efficient masking technique can be accomplished by covering the mouth and nose with one mask and inserting a sheet of plastic over the mouth under a second mask.

Simple Thigh Support to Replace Thomas Splint and Pearson Attachment in Certain Cases. Dr. David I. Schwartz [44] said that for many years, when skeletal traction has been indicated in the treatment of certain femoral conditions, the usual method of supporting the extremity has been balanced traction on a Thomas splint with Pearson attachment. This method has proved cumbersome. Unless the patient is very cooperative, the system soon becomes out of balance, requiring adjustment. In numerous instances, the adjustments are necessary many times a day—and frequently at night—with telling effect on the morale of nurses, doctor, and patient.

To eliminate these constant adjustments, Dr. Schwartz constructed a simple wedge-shaped device with a canvas hammock top. The device is placed under the thigh to support the femur. At the same time it allows sufficient flexion of the knee joint so that skeletal traction can be exerted without interference. The wedge, made of wood, rests on the mattress and extends from the region of the trochanter to just proximal to the knee joint.

The thigh-supporting wedge method of treatment, admittedly, is not a balanced system. It does, however, provide flexion of the knee and adequate, comfortable support of the entire thigh. Moreover, traction on the femur is in proper line of pull direction. The wedge is applied quickly and easily and does not require frequent or professional adjustments. In addition, it is effective, simple, inexpensive, and readily available.

Laminagraphy, a Method of Evaluating Fracture Healing. Dr. Irvin Stein [45], Dr. Robert R. Richter, Dr. Philip J. Hodes, Dr. Bernard Ostrum, and Dr. Martin L. Beller utilized clinical cases and post-mortem studies to demonstrate the effectiveness of body-section roentgenography (planography, laminagraphy, and tomography) in the treatment of fractures of the proximal end of the femur. In body-section roentgenography, selective layers within the body can be demonstrated. In the focal plane one level alone is shown clearly; all other parts are blurred and indistinct. In studying hips, from 25 to 30 degrees of amplitude of tube motion and a focal-plane level of bone about four millimeters in thickness give the best visualization. The direction of travel of the tube should be approximately parallel to the long axis of the fracture, not the long axis of the limb, unless the two coincide.

Fractured hips were studied by serial, routine roentgenograms and by body-section roentgenograms. In many instances, the body-section roentgenograms provided data in regard to union or non-union of femoral-neck fractures sooner and more conclusively than routine roentgenograms. A number of limbs showed a phenomenon, which has been denoted as *peri-fracture*

41. 1539 Delachaise Street, New Orleans 15, Louisiana.
42. 233 North Prairie Avenue, Inglewood, California.
43. 3244 East Douglas, Wichita 8, Kansas.
44. 44 Douglas Road, Delmar, New York.
45. 1936 Spruce Street, Philadelphia 3, Pennsylvania.

deossification. The evidence so far suggests that when peri-fracture deossification exists, non-union will result.

Present post-mortem studies, with specimens embedded in paraffin to approximate the normal thickness of the part when the last routine roentgenographic studies were made, further demonstrated the ability of body-section roentgenography to show more accurately the presence or absence of bone union at each level. Body-section roentgenograms correlated more closely with the roentgenograms of coronal post-mortem slices of the upper femora than roentgenograms made before death in showing union or non-union.

It would therefore appear that the ability of body-section roentgenograms to bring out details of fracture healing at a given focal plane level is unique. The book-cassette type of body-section roentgenography is ideal as a screening procedure, and is often definitive in the more slender patients. The best data were provided by body-section roentgenography at multiple levels of exposure for maximum detail and roentgenographic information.

Surgery of the Arthritic Hand. Dr. Lee Ramsay Straub [46], Dr. Rolla D. Campbell, Jr., Dr. Robert C. Mellors, and Dr. John L. Sbarbaro said that the purpose of their exhibit was to stimulate interest in the possible surgical reconstruction of the rheumatoid arthritic hand.

In discussing the role of synovial reaction, the authors pointed out that synovitis is the direct or indirect cause of the deformities to be treated. Enlarged photomicrographs demonstrated the histological changes, with the rheumatoid factor in synovial tissue illustrated by fluorescin stains. The rheumatoid nodule was also illustrated.

Enlarged color transparencies, used to illustrate the preoperative, the operative, and the postoperative condition in sample cases showed the correction of specific deformities. Destruction of the extensor tendon by synovitis was illustrated. This pointed up the need of prophylactic synovectomy when conservative measures fail to give relief. Tendon weakening after synovitis and the mechanical factors that helped to produce rupture were attributed to: pressure of the dorsal carpal ligament; and erosion through pressure on irregular bone surfaces, such as the dislocated distal ulna and the irregularities of Lister's tubercle.

In discussing the etiology and treatment of ulnar drift, the authors said that an early case is treated by synovectomy and tendon replacement; later cases by resection of the metacarpal heads, with tendon replacement and fixation.

Also discussed were: restoration of stability to dislocated joints; arthrodesis of the thumb metacarpophalangeal joint; and the approach to the intrinsic positive and boutonnière deformities in rheumatoid arthritis.

It is the author's conclusion that although most results are not dramatic, the patient with an arthritic hand can make very satisfactory gains after carefully considered and executed surgical reconstruction.

Correction of Idiopathic Scoliosis and Dorsum Rotundum by Double Flexion and Fulcrumage. Dr. David R. Telson [47] designed his exhibit to counteract a defeatist attitude in regard to conservative treatment of scoliosis and dorsum rotundum.

In idiopathic scoliosis the degree of flexibility is of greater prognostic value than either chronological or bone age (iliac-crest maturation). A curve may be rigid at eleven years of age and flexible at fifteen. Treatment of the flexible curve involves two distinct and separate problems: (1) obtaining correction, and (2) maintaining correction.

Dr. Telson said that correction is obtained by double bending and fulcrumage, and described the right total 'C' curve. There are two segments of the curve, the upper thoracic and the lower lumbar.

The lower segment enters the pelvis at an acute angle. This is changed to a right angle by bending the trunk to the left. A padded cast is applied high on the right, placing the fulcrum opposite the apex of the curve. The patient is then bent back to the right, breaking the curve at the fulcrum. The cast is extended up to the left axilla. Additional felt pads, three-quarters of an inch thick, are forced into the fulcrum twice weekly. The patient is able to walk and usually continues going to school.

To maintain correction the cast is removed in three or four weeks and a quadrilateral brace is applied. The brace is worn for one to three years, during which time exercises for posture are carried out. Roentgenograms and chart-paks, made every three months, indicate the patient's progress. When roentgenograms with and without the brace are identical, the brace is discarded.

In the correction of a right thoracic-left lumbar curve the lower segment of the lumbar curve is brought to a right angle of the pelvis by a sharp bend to the right, placing the fulcrum at the apex of the lumbar curve. The patient is then bent to the left, placing the second fulcrum at the apex of the thoracic curve. There is a voluntary pressure on the thoracic curve against the second fulcrum. The cast is removed in three or four weeks, a quadrilateral or scissors brace is applied, and exercises for posture are carried out. Upright roentgenograms, made every three months, are transferred to chart-pak graphs to determine if other measures are needed.

46. 535 East 70th Street, New York 21, N. Y.
47. 950 Ocean Avenue, Brooklyn 26, New York.

Rigidity of the thoracic curve on manual examination is the prognostic criterion in dorsum rotundum. As in scoliosis, the first step is the correction of the relationship of the lower lumbar spine and the anterior lordotic curve to the pelvis. Hip flexion contractures are usually present. The patient is sharply flexed forward and a cast is applied from the crease of the buttocks to the apex of the thoracic curve. A padded fulcrum is formed here. Because of the contracted iliopsoas the patient will be unable to straighten up completely for a few days. By this flexion, lumbar lordosis is changed into kyphosis although dorsum rotundum is increased temporarily. A steel-spring cross bar is embedded in the cast and the straps are tightened twice weekly. The dorsum rotundum is corrected by the fulcrum. The cast is taken off in three weeks and a cowhorn brace is applied. Exercises are carried out for one to three years.

The method of correction of the curve differs from most other methods in use in the following principles: Distraction *per se* is never employed. The correction of both the lateral and the posterior curvature in both groups depends on an establishment of a fulcrum, which is placed as far to the left as possible in the right total 'C' curve and as far forward as possible in the posterior dorsum rotundum curve. When this fulcrum has been established by the first half of the cast, the correction is obtained by leverage of the upper segment of the curve by plaster in the case of scoliosis, and by the steel spring in the case of dorsum rotundum.

A contour line is described on a plastic sheet, seven by seventeen inches, to chart the correction of the curve. The lines are made by superimposing the plastic sheet over the fourteen by seventeen-inch film on a light box and tracing the curve with chart-pak or ACS tapes. The original curve is traced in black. The same plastic sheet is superimposed on the spine in the plaster jacket and traced in red. A similar procedure with the child in the brace is traced in white. The lumbosacral junction is superimposed on each upright roentgenogram of the spine. (The tracings of forty patients were shown at the exhibit. In addition to the progress of the curve the tracings showed the amount of compensation attained in the relationship of the shoulder to the pelvis.) In the treatment of patients at either the hospital or the office, the plastic sheet is filed with each envelope containing the roentgenograms, and new roentgenograms are simply superimposed upon the original sheet to show progress. In dorsum rotundum, a Japanese curved ruler is forced against the back and traced onto a plastic sheet. After treatment the same ruler is used, with the curve superimposed in different colors.

Brittain Arthrodesis of the Hip, Follow-up Study. Dr. David G. Vesely[48] described various types of hip fusions, including those used in the past. Dr. Vesely discussed the end results of forty ischiofemoral fusions, and illustrated an improved type of double-compression, tibial-graft fusion of the hip.

Use of an I-Beam Nail for Fractures of the Radius. Dr. David G. Vesely[48] illustrated the advantages of an I-beam nail, from an engineering viewpoint. He described the retrograde insertion of the nail, and discussed clinical examples of its use.

Oscillating Plug Cutter to be Used in the Dowel Cervical Body Fusion. Dr. Ben R. Wiltberger[49] exhibited a plug-cutting instrument, plastic models of a dowel-type cervical-body fusion, and a small ruler, in millimeters. A roentgenogram of a dowel-type cervical-body fusion was also displayed.

The plug cutter is attached to an oscillating electric motor to cut precisely the cylindrical hole between the cervical vertebral bodies when performing a dowel-type vertebral body fusion of the cervical spine from an anterior approach.

When making roentgenograms at operation, the small ruler, in millimeters, is used to determine the exact setting for the depth gauge on the end-cutting plug cutter.

Ununited Fractures of the Carpal Navicular — Treatment by Combined Bone-Grafting, Internal Fixation with Vitallium Lag Screw, and Radial Styloidectomy. Dr. Mihran O. Tachdjian[50], Dr. Philip H. Davis, and Dr. Coursen Conklin discussed a consecutive series of twenty-eight ununited fractures of the carpal navicular in twenty-six patients. These fractures were treated by combined bone-grafting, internal fixation with a Vitallium lag screw, and radial styloidectomy. Each patient operated on had a painful, weak, and stiff wrist and was unable to perform his duties. The minimum time between injury and operation was ten weeks; the maximum, four years. The time was unknown in five fractures. The average time in known cases was one year and six weeks. Twenty of the twenty-eight fractures had not previously been treated, but the remaining eight had been immobilized in a cast for varying periods of time. Roentgenographic evidence of aseptic necrosis of the proximal fragment was present in seven of the twenty-eight carpal naviculars. One of the fractures was complicated by transscaphoid perilunar dislocation. The minimum follow-up was six months and the maximum was two years and three months; the average, one year and one month. Sixteen of the twenty-eight fractures were followed for over

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one year; five of the sixteen were followed for over two years.

In describing the operative technique, the authors said that radial styloidectomy is done first to help exposure of the carpal navicular. The site of osteotomy is just proximal to the fracture line, with the hand in radial deviation. The drill point for the lag screw is started at the dorsolateral aspect of the tubercle of the navicular bone and aimed subcortically, staying on the dorsoradial aspect. The drill point for the bone graft is started anterior and medial to the drill point for the screw. The second drill point holds the fracture fragments together as the Vitallium lag screw is inserted and serves as a channel for the matchstick-bone graft, which is taken from the distal radius. Roentgenograms should always be made in two planes to check the position and length of the screw and bone graft. A short arm cast is then applied. This is worn for only two weeks, after which aggressive physical therapy is started and continued until maximum range of motion is obtained.

Clinical and functional end results have been excellent or good in all fractures. The rapid relief of symptoms and the return of normal function have been surprising; all patients returned to normal activity four to six weeks after operation. Bone union was achieved in eighteen of twenty-eight fractures (64.3 per cent). In three of the seven fractures with avascular necrosis of the proximal fragment, there was roentgenographic evidence of vascularization.

The authors advocated primary internal fixation with a Vitallium lag screw and bone-grafting when there is a transscaphoid perilunar dislocation with the carpal navicular fracture. One such case was presented.

AMERICAN SOCIETY FOR SURGERY OF THE HAND

The Fifteenth Annual Meeting of the American Society for Surgery of the Hand was held on January 22 and 23, 1960, in Chicago, Illinois, under the Presidency of Dr. Julian M. Bruner of Des Moines, Iowa.

On January 21, 1960, the Society met for a one-day clinical session in Iowa City, Iowa, at the State University of Iowa; the program was organized by Dr. Adrian E. Flatt.

Bone and Joint Changes Associated with Thermal Burns. Dr. R. T. Tidrick[1] stated that bone and joint changes develop in 10 per cent of burns. He discussed twenty-four patients who showed such changes; thirteen had joint derangements, seven had osteomyelitis, two had myositis ossificans, and two had osteoporosis. As a rule, there were mixed infections, but *Staphylococcus aureus* was invariably present, associated with *Proteus vulgaris* and *Pseudomonas aeruginosa*. He emphasized the importance of obtaining cultures from infected joints early, stating that, as a rule, joints involved with saprophytes did not fuse, whereas fusion usually resulted in joints in which *Staphylococcus aureus* was present. Early incision with drainage was stated to be important in treatment.

The Design of Handles for Industry. Dr. John H. Schulze[2] said that most previously designed handles have been designed on the basis of a common-sense approach, but this is no longer adequate, and scientific human engineering must play a role in design. This is seen particularly in surgical instruments, where what is designed is frequently what one is familiar with, and not necessarily what would be best suited to accomplish the purpose.

A Case of Locked Index Finger. Dr. Julian M. Bruner[3] reported on a finger that had clinically resembled a trigger-finger; it would lock in flexion but could be unlocked by a movement combining clockwise rotation and extension at the metacarpophalangeal joint. The locking was found to be due to a crescentic membrane within the joint that caught on the head of the metacarpal in flexion and thus prevented extension. This membrane was only identified after the joint was opened.

Anatomical Anomalies within the Hand. Dr. Eugene W. Scheldrup[4] described both vascular and nerve anomalies that occur within the hand.

Techniques in Hand Surgery. Mr. R. Guy Pulvertaft[5] emphasized that he was using internal fixation for fractures of the hand more and more. He seemed to prefer the plantaris tendon as a source for tendon grafts. For the secondary repair of old mallet-finger deformities, he stated that he resects a segment of the extensor tendon and then reapproximates the tendon with fine silk; he used a similar technique to repair the extensor tendon in boutonnière deformities of the proximal interphalangeal joint. He stated that 75 to 80 per cent of his tendon grafts were successful. He favored secondary nerve repair over primary repair and believed that nerve grafts were to be used when necessary and that success could be expected after these grafts. When doing tendon transfers for the treatment of radial-nerve paralysis, he preferred to leave the flexor carpi radialis as a wrist flexor, using the pronator radii teres, the flexor carpi ulnaris, and the palmaris longus as motors.

Prosthetic Replacement of Rheumatoid Finger Joints. Dr. Adrian E. Flatt[6] illustrated his technique in which he uses a modified Brannon prosthesis to replace the completely destroyed proximal interphalangeal joints of patients with rheumatoid arthritis. In the clinical presentations during the afternoon session, several of these patients were available for clinical examination. Several of the reconstructed interphalangeal joints showed good ranges of motion.

In the afternoon session, several patients with certain conditions, such as congenital anomalies and rheumatoid deformities of the hand, were available for examination, together with their preoperative photographs and roentgenograms so that the clinical problem and the result obtained could be evaluated.

Friday, January 22, 1960

Extension of the Distal Phalanx of the Thumb. Dr. R. M. McFarlane[7] reported on his observations that, after division of the ulnar nerve, weakness of extension of the distal phalanx of the thumb occurs, which becomes apparent during the action of pinch. This deformity was described by Froment, in 1915, as being due to paralysis of the adductor pollicis muscle and the

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5. Derby, England.
6. University Hospitals, State University of Iowa College of Medicine, Iowa City, Iowa.
7. The University of Western Ontario, London, Ontario, Canada.

resultant inability of this muscle to extend the distal phalanx of the thumb. Froment described a test for adductor paralysis that he called "the sign of the thumb".

Because Froment's test is not generally used and because other explanations of the deformity have been offered, an anatomical and clinical study of the problem was carried out. The study supported Froment's view that adductor paralysis results in the inability of the distal phalanx of the thumb to remain extended during the action of pinch.

In discussion Dr. J. Leonard Goldner [8] agreed that paralysis of the adductor pollicis muscle after division of the ulnar nerve does weaken the thumb, but with lesions of this nerve he believed that Froment's sign was not superior to testing of the strength and feeling of the contraction of the first interosseous muscle, with the metacarpophalangeal joint of the thumb locked in hyperextension. The intrinsic muscles of the thumb, in his opinion, are not the initiators of extension of the distal phalanx; this movement is initiated by the long extensor and short extensor muscles, supplemented by the lateral-band action of the adductor and abductor.

Dr. William L. White [9] indicated that the adductor may not be the main extensor of the distal phalanx of the thumb. He also felt that it was primarily a stabilizer of the metacarpophalangeal joint. He emphasized that the adductor really is made up of two components, being similar to the volar interosseous muscles in the fingers.

Dr. McFarlane, in closing, indicated that the adductor really has four functions: (1) to supinate the thumb; (2) to approximate the thumb metacarpal to the index finger; (3) to extend the terminal phalanx; and (4) to stabilize the metacarpophalangeal joint.

An Experimental Study of Digital Flexor Tendon Healing. Dr. W. K. Lindsay [10] reported a large series of experimental studies designed to investigate the variables in the repair of the digital flexor tendons. The experimental animal was a chicken because the anatomy of its flexor tendon is comparable to that of the human being. The percentage of return of function after various procedures was as follows: simple incision of the skin, 100 per cent; excision of the flexor sublimis tendon, 60 per cent; excision of the tendon sheath, 100 per cent; suture in the flexor profundus tendon only, 25 per cent; and suture and laceration of the flexor sublimis, 45 per cent; and laceration and suture of the flexor profundus, 16 per cent. Excision of the vinculae in combination with any of these experimental procedures resulted in an additional loss of function amounting to 25 per cent. Types of trauma and the extent of the gap formed between the tendon ends were considered in relation to functional return. The author recommended immobilization of four to five weeks and guarded motion during a two-month period. The use of anti-inflammatory agents, such as cortisone or hyaluronidase, under experimental conditions, appeared to achieve a significant improvement in the functional return and a delay in cellular responses, but these agents are not as yet suggested for use in human beings.

Dr. J. Edward Flynn [11], in the discussion, considered the process of tendon repair and the source of callus in tendon healing. In his experiments, anti-inflammatory agents did not improve the end results. He discussed the stages of healing, including cellular response, collagen formation, and the reaction in the tendon sheath. Tribute was paid to Dr. Michael Mason, whose paper of twenty-five years ago still stands as a classic in this field.

Observations in Roller Injuries: An Experimental Study. Dr. John P. Adams [12] and Dr. Francis D. Fowler [13] presented a study of the pathological changes in two groups of Wistar rats weighing 60 to 80 grams. The first group was subjected to crushing roller injury in a hand-operated wringer for sixty seconds, and the second group subjected for 300 seconds.

The clinical findings in each group were similar in the acute phase, but the more severely injured animals required a longer interval for recovery. The gross specimens demonstrated earlier and more definitive changes in the animals subjected to the injury for 300 seconds. The microscopic changes in each group were patchy, often near the bone. In no instance was there generalized involvement of all muscles.

The authors believed that the pathological changes in roller injuries are primarily due to muscle and soft-tissue injury with subsequent edema and venous and lymphatic obstruction. These changes are followed by necrosis of muscle fibers, proliferation of fibrous tissue, and ultimate fibrosis and contracture if the trauma is extensive. Arterial insufficiency is probably secondary and is related to the severity of the injury.

Dr. Martin Entin [14], in discussion, disagreed with the authors because he believed that there was not sufficient microscopic evidence for the statement that damaged muscle cells regenerate. He also believed that the release of potassium by the damaged muscle played a role in the development of the changes seen.

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13. Georgetown University Hospital, Washington, D. C.
14. 373 Medical Arts Building, Montreal, Quebec, Canada.

DR. JOHN L. BELL[15] did not believe that the experiment had proved conclusively that compression dressings could prevent the progressive changes.

Ischemia Resulting from Tourniquet Application to the Extremity. DR. F. X. PALETTA[16] studied changes in muscles, tendons, and nerves after the application of a tourniquet for periods of from one to five hours. Irreversible destructive changes occur after four to five hours. The influences of heparin and hypothermia were studied in reference to post-tourniquet changes. It was concluded that the safe upper limit of time for a tourniquet in man is not yet defined, but that the conventional period of two hours is safe. Four hours was the critical time in the dog. After a tourniquet had been applied for five hours, edema lasted for as long as one week. Heparin prevented, in large measure, neurological manifestations, such as drop-foot, and favored the return of normal temperature to the skin and muscles. The mechanism of the favorable action of heparin and hypothermia on this controlled injury was not established.

In discussion, DR. WILLIAM L. WHITE[9] stressed the clinical aspects of the use of a tourniquet, emphasizing the importance of the level where the tourniquet is applied with reference to the underlying bone and the amount of soft tissue, and the amount of pressure applied. He discussed the development of wound engorgement despite the use of a tourniquet and commented on the depth of anesthesia and the use of other agents, such as anectine. He recommended speeding the early phases of wound management as a means of shortening tourniquet time, as did DR. GEORGE V. WEBSTER[17], who also briefly discussed the subject.

Experience with Cross-Finger Flaps. DR. J. WALLACE MCNICHOL[18] and DR. ORVILLE J. MIREHOUSE[19] discussed their experiences with 101 cross-finger pedicle flaps; ninety-three of these were single flaps, seven were double flaps, and one was a triple flap. The authors prefer a cross-finger flap for the replacement of loss of a finger tip, raising a flap on the dorsum of the middle phalanx and flexing the injured finger to bring its tip into contact with the flap on the donor finger. The two fingers are immobilized by a small plaster splint. The laterally based flap was preferred for a pulp defect. A distally based flap was preferred for a guillotine amputation of the finger tip. For a thumb defect, either a proximal or mid-dorsal flap from the dorsal aspect of the middle phalanx of the long finger was used.

In discussion, DR. ROBERT M. MCCORMICK[20] emphasized how impressed the audience was with the beautiful colored slides illustrating nine of the 101 cases. He raised the question as to whether the plaster applied to the skin of the fingers might not cause some secondary swelling.

DR. DARREL T. SHAW[21] congratulated Dr. McNichol on his fine presentation and on the number of cases he was presenting. He emphasized, however, the importance of recognizing the fact that joint stiffness may occur in older patients and that in some of these individuals another type of skin coverage may be preferable, even though the pedicle flap does provide the finest type of replacement where skin and fat have been lost.

Surgery of the Arthritic Hand. DR. LEE RAMSAY STRAUB[22], DR. ROLLA D. CAMPBELL, JR.[23], and DR. JOHN L. SBARBARO, JR.[24], discussed tissue changes and resulting anatomical alterations in hands affected by rheumatoid arthritis. Included in this discussion were the nature of the rheumatoid nodule and of the synovial reaction with invasion of tendon and bone, displacements of the extensor tendons, leading to ulnar drift of the fingers, the development of the intrinsic-plus deformities, volar dislocations at the metacarpophalangeal joints, and spontaneous tendon ruptures. In the surgical treatment of these finger deformities the lateral bands, if fused to the central tendinous slips, are freed by dissection, and the central extensor tendon is lengthened. Great emphasis was laid on the value of prophylactic synovectomy; no local exacerbations of the arthritis in these joints was observed in later flare-ups of the disease in patients who had had synovectomies.

In discussion, DR. DANIEL C. RIORDAN[25] commented on the weakening of the transverse fibers of the extensor hood by synovial proliferation and further discussed methods for correction of ulnar drift of the fingers. He discussed the use of cortisone derivatives and also mentioned the use of nitrogen mustard. In some patients with involvement of both hands, treatment with nitrogen mustard had been followed by the disappearance of swelling on the side on which no surgery had been performed, whereas the other hand remained swollen for two months after operation.

DR. ADRIAN E. FLATT[6] likewise advocated prophylactic synovectomy as well as partial sectioning of lateral ligaments where necessary. He believed that the first dorsal interosseous muscle is

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22. 535 East 70th Street, New York 21, N. Y.
23. 30 East 72nd Street, New York 21, N. Y.
24. Hahnemann Hospital, Philadelphia 2, Pennsylvania.
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always weak and wasted in arthritic hands and that this favors ulnar drift. He, therefore, always transfers the extensor indicis proprius to the first dorsal interosseous tendon in conjunction with synovectomy. He recommended fusion of the metacarpophalangeal joints for gross deformities. He believed that arthroplasty may have a place in this disease, but he placed great emphasis on early surgery.

In closing the discussion, Dr. Straub stressed correction of drifts by appropriate transplants. He believed that prolonged use of steroids may lead to tendon rupture.

Complicated Syndactyly: "Timing" and "Procedures" for Correction. Dr. William H. Frackelton[26], Dr. Jack L. Beasley[27], and Dr. Bryon A. Genner, III[28], presented a survey of eighty-three patients with syndactyly. Of these, twenty-four were found to have associated anomalies of various types. Each of the patients had had one or more operations during his treatment. One hundred and thirty-seven different procedures had been performed.

Where there was fusion of the phalanges distally, it was believed that these tips should be released early. Z-plasty was carried out early in some instances for correction of digital angular grooves and selective excision of accessory bones where indicated. Duplicated tendons were removed, and tendoplasty was carried out where rerouting would lessen the angulatory stress. Tendon transfers were carried out where weak interosseous muscles needed additional muscle strength. Capsuloplasty and arthroplasty proved successful in some instances. Accessory bones were removed, and angulatory osteotomies were performed in several instances. Syndactylism was corrected when the children were between the ages of four and six years if there was no reason to perform the procedure earlier.

In discussing Dr. Frackelton's presentation, Dr. Arthur J. Barsky[29] heartily agreed with the terminology that he used, that is, terms based on Greek roots. He pointed out that anomalies that involve the hand, particularly in cases of ectrodactylia, often affect not only the hand, but the entire upper extremity as well. He presented roentgenograms of a patient, pointing out how the early roentgenogram may be misleading in the congenitally deformed hand, since later roentgenograms may show bone development in parts of the hand where, earlier, there had been no indication that these bones were present.

Dr. Walter Graham[30] emphasized the value of full-thickness skin grafts for the closing of exposed areas that are formed during the correction of syndactylia. Procedures on the soft tissue are done before the child reaches school age; corrective osteotomies, if needed, are done at a later date.

Tendon-Grafting for Division of the Flexor Profundus. Mr. R. Guy Pulvertaft[5] stated that if the condition of the wounds permits, primary repair of lacerations of the flexor profundus tendons can be done, provided that the site of the division is within one and one-half centimeters of the distal flexion crease of the finger. Later treatment of injuries of the flexor profundus without involvement of the flexor sublimis tendon includes arthrodesis, tenodesis, and tendon-grafting. Tendon-grafting is done for a relatively small number of injuries, usually for those in the index and long fingers where the conditions are favorable and when the patient demands that the procedure be done. It is very occasionally done in the ring and the little fingers for patients with special occupations, such as musicians. Arthrodesis or tenodesis is done for laborers. Technical considerations include the removal of the entire sheath, preservation of pulleys, suture of the proximal portion of the tendon done first, and distal fixation by a wire loop through the distal phalanx or by the Bunnell pull-out-wire method. The traction wires are drawn straight through the bone tufts, using intravenous needles as guides. A tourniquet is used, but no hypotensive agents. No ligatures are used. Immobilization, including the normal fingers, is maintained for three weeks. Steel wool is a suitable springy material for occlusive dressings. During the fourth week after operation, adhesive strapping over the finger tip is used as a restraining strap. Mr. Pulvertaft showed a film illustrating his method. Short incisions were used, and the palm was dissected first. The plantaris tendons and the extensor tendon to the fourth toe are used as tendon grafts.

In discussion, Dr. Sumner L. Koch[31] emphasized the importance of accurate and sharp dissection, patient and painstaking surgery, complete hemostasis, and gentle handling of the tissues as factors that all favor perfect healing and the preservation of the gliding mechanism. In transections of the profundus tendon alone near the second finger joint, local fibrosis may prevent gliding, and, rarely, complete removal of the flexor sublimis may be warranted. Arthodesis is an admission of failure and is rarely advised. For the repair of tendons, fine untreated white silk is preferred. Incisions in the fingers are made in front of the nerve because this location seems to favor hemostasis. In the performance of a tendon graft, the distal end is sutured first, and then the proximal end is cut in the form of a wedge and inserted into the proximal stump of the tendon without weaving it through the stump. A tendon from the dorsum of the foot with its covering kept intact by removing

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31. 154 East Erie Street, Chicago 11, Illinois.

the tendon and its coverings from the foot by dissection and not by force is preferred as a graft. Blood vessels are clamped before they are divided and are tied with fine silk. A case was cited of secondary tendon suture that was performed two months after injury, in which full flexion from an extended position of 160 degrees at the distal joint was obtained.

Dr. Lot D. Howard, Jr.[32], described Dr. Bunnell's meticulous technique and expressed his admiration for Mr. Pulvertaft's results, which he thought were due possibly to ". . . those British hands being more limber than ours". Dr. Howard stated that he never uses the plantaris tendon as a graft for a flexor tendon. An important cause of dysfunction after tendon-grafting may be fibrous cordlike adhesions to the lumbrical muscles or deep fascial adhesions, which cause local fixation of the graft. An adequate flexor mechanism may be nullified by extension of the distal phalanx caused by the lumbricals.

The Appearance of Boeck's Sarcoid in the Hand. Dr. Robert E. Carroll[33] discussed 151 cases of Boeck's sarcoid reviewed during the period between 1935 and 1958, in twenty of which there was involvement of the hand. One-third of these twenty patients presented themselves because of swelling in the hand. All of them had elevation of the sedimentation rate and of the serum calcium, and 90 per cent of them had skin lesions. Dr. Carroll pointed out that the early roentgenographic changes in the bones resembled Swiss cheese, whereas in the later stages of the disease, larger areas of rarefaction appeared in the small bones of the hand. In the differential diagnosis, hypoparathyroidism, Cooley's anemia, leprosy, tuberculosis of bone, Ollier's disease, normal vascular channels, hemangiomata, and arteriovenous fistulae, as well as the various granulomata of the bone, must be considered.

In discussion, Dr. George S. Phalen[34] complimented the author on the presentation. Dr. Phalen pointed out that the histological changes in the bone lesions are not diagnostic. If the skin is also involved, the microscopic changes are more characteristic, and the pathologists can be a little more certain of their diagnosis. Dr. Phalen emphasized that the roentgenograms of sarcoid can be quite confusing. With regard to treatment, he stated that he had used large doses of vitamin B, and, recently, cortisone. In most of the patients now being treated, Dr. Phalen indicated that isoniazid, in doses of 100 milligrams three times a day, was being used.

Osteosarcoma Superimposed upon Osteitis Deformans in the Phalanges of the Hand. Dr. Benjamin W. Dromp[35] reported an unusual case of an elderly Negro in whom osteogenic sarcoma developed first in the proximal phalanx of the right long finger and then, three years later, in the corresponding phalanx of the left index finger. In both instances there appeared to be preexisting osteitis deformans in the involved bones. Both lesions were treated by resection of the involved ray. Two years and eight months after the second amputation there was no evidence of local recurrence or metastasis. The first lesion was originally diagnosed as a chondrosarcoma, but the diagnosis was subsequently changed to osteogenic sarcoma. Roentgenograms of the skeleton revealed changes in the right tibia and second lumbar vertebra that were considered to be characteristic of early osteitis deformans. Repeated determinations revealed the patient's alkaline phosphatase to be normal.

Dr. Howard C. Hatcher[36] raised the question of whether in this patient there was a second primary tumor or a metastasis to an area previously involved by Paget's disease. He noted that bones involved by Paget's disease are often preferred sites for metastases to bone. He speculated on the cause of Paget's disease and the cause of the localization of tumor metastases in Paget's disease.

Dr. Robert E. Carroll[33], in discussion, presented a case of osteogenic sarcoma in the fifth metacarpal in a patient with Paget's disease who likewise had extensive sarcoma in the spine and both femora.

Management of Fractures of the Greater Multangular. Dr. Lee J. Cordrey[37] said that fractures of the greater multangular are not uncommon and are of significance because of involvement of the important carpometacarpal joint of the thumb. From a survey of the world literature it appears that fracture of this bone occurs most commonly in combination with other fractures about the wrist. Isolated fractures may be of the avulsion type or they may result from impaction, in which case the fracture is parallel to the long axis of the metacarpal of the thumb with proximal displacement of the radial fragment of the greater multangular along with the metacarpal. Isolated fractures are frequently not diagnosed early because there are few clinical findings initially, and roentgenographic examination by routine projections may not disclose the fracture. Oblique positioning of the thumb is necessary to produce a true anteroposterior projection of the multangular.

The gross and functional anatomy of the greater multangular were discussed, and five cases were presented. Review of the literature disclosed no agreement as to the specific treatment of

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37. 4801 Woodmere, Tampa 9, Florida.

injuries of the greater multangular. Open reduction and internal fixation with one or two Kirschner wires to provide stable anatomical reduction and restore the articular surfaces of the first carpometacarpal joint were advocated by the author. The technique of approach and the method of treatment were briefly described.

In the discussion, Dr. Carruth J. Wagner[38] said that fractures of the greater multangular are rare, and isolated fractures are even more rare. This, of course, is owing to the fact that this fracture usually results from indirect rather than direct violence. In the usual case, there is a fracture-dislocation of the first carpometacarpal joint, with the multangular fracture accompanied by Bennett's fracture of the first metacarpal, avulsion of the radial aspect of the base of the second metacarpal, or both. Isolated fractures, as indicated in the author's series, are almost invariably due to direct blows to the wrist.

The diagnosis is not always easy because the usual roentgenograms of the wrist reveal the greater multangular to be overlapped partially by the lesser multangular, the navicular, and the first and second metacarpals. Dr. Wagner said that he has found it helpful in studying roentgenograms of the wrist or hand to check routinely the relationship between the proximal heads of the first and second metacarpals; when the greater multangular is fractured their normal relationship is usually disturbed. Oblique views are then indicated, which will usually demonstrate the fracture line quite well.

The greater tubercle of the greater multangular lies on the volar aspect of the bone. This tubercle has a deep groove on its basal and ulnar sides. The tendon of the flexor carpi radialis muscle lies within this groove. Sometimes, the tubercle produces an impression of a fracture fragment on roentgenograms. As Dr. Cordrey indicated, there is no good way of demonstrating the volar aspect of the greater multangular in a roentgenogram. The lack of displacement of the carpometacarpal joint usually serves to rule out a fracture, and if the patient has no pain on resisting the pull of the flexor carpi radialis, a fracture of the tubercle should not be anticipated.

Dr. Wagner agreed with Dr. Cordrey that fractures of the greater multangular that are displaced and cannot be reduced by manipulation and maintained in position should be treated by open reduction with the use of Kirschner wires for fixation. Dr. Wagner preferred a volar, radial, longitudinal incision along the proximal third of the first metacarpal and reflection of the thenar muscles from the metacarpal and the capsule of the carpometacarpal joint. Excellent exposure can be obtained by this approach without danger of trauma to the cutaneous branches of the radial nerve or radial artery.

Restoration of Hand Function by the Use of Partial or Total Prosthetic Replacement. Dr. Alfred B. Swanson[39] discussed the function of the hand in pinch, grasp, stroke, strike, and push. He pointed out that prostheses cannot replace all these functions. With an intact thumb and loss of the remaining fingers, a prosthetic glove with a space cut out for the thumb gives function with some sensory surface. Various other types of prosthetic devices for use after total or partial amputation of the hand were also illustrated. Prosthetic fingers, as a rule, were only of value to improve appearance. Children, in some instances, exhibited a remarkable capacity for adjustment to their prosthetic appliances.

In discussion, Dr. Donald B. Slocum[40] said that improved appearance and restoration of function are tests for reconstructive surgery. Reconstruction is superior to any artificial measure. Sensory areas should never be covered by a prosthesis. The essential features of a prosthesis are fit, comfort, and durability. A prosthesis should be designed to be "within the gadget tolerance" of the wearer and should also be designed for the work for which it will be used.

Saturday, January 23, 1960

Composite Graft of Bone, Joint, and Tendinous Structures in Complete Construction of a Digit. Dr. Herbert Conway[41] gave a case presentation of a nine-year-old girl born with multiple congenital anomalies of the digits of both hands and both feet. The right hand had rudimentary digits involved by a mass of scar tissue. When the child was three years of age, the digital stumps on the right were separated, and when she was seven years of age, the index and ring fingers were lengthened to approximately normal length by pedicled flaps from the abdomen. Six months ago, the soft-tissue pedicle on the right index finger was supported by the transplantation into it of a composite free graft consisting of the phalanges, joint structures, and tendons—all taken in one piece from the second toe. At the time of reporting, the finger was functioning well, and the sensation in the pedicled tissue was estimated to be approximately 50 per cent of normal.

In discussion, Dr. Erle E. Peacock, Jr.[42], noted that this ingenious operation raised many interesting points for discussion, but he confined his remarks to the fate of the articular cartilage of the transplanted joints. Because of its low oxygen and nutritional requirements, one might expect the cartilage in a composite tissue graft to be very stable after transplantation. In his experience

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41. The New York Hospital, 525 East 68th Street, New York 21, N. Y.
42. University of North Carolina, School of Medicine, Chapel Hill, North Carolina.

with composite tissue grafts of joints, the articular surfaces degenerate relatively rapidly. An example of rapid degeneration of the articular surfaces of a transplanted joint and early closure of transplanted epiphyses was shown in the roentgenograms of a five-year-old girl who suffered a gunshot wound of the center of the hand. The proximal interphalangeal joint from the irreparably damaged long finger was transferred to replace the destroyed metacarpophalangeal joint of the ring finger. Postoperative roentgenograms showed complete degeneration of the joint surfaces and closure of the epiphyses nine months after transfer. Despite these findings, remarkably good function was present two and a half years after the transfer.

The degeneration of the hyaline cartilage transplanted within a joint capsule, the unusual susceptibility of cartilage to infection, and the reaction of cartilage to the presence of overlying granulation tissue or pannus are interesting phenomena that cannot be satisfactorily explained at this time. Transplantation of cartilage for functional purposes, however, such as in the patient reported by Dr. Conway, emphasizes the need for more basic knowledge about articular cartilage.

Opposition of the Thumb and Its Restoration. Dr. Bernard Jacobs[43] and Dr. T. Campbell Thompson[44] said that tendon transfers are designed to prevent or correct fixed deformities. The preferred muscle motor is the flexor sublimis to the ring or long finger. The pulley should be fixed firmly and placed at a distance from the axis of the thumb ray. The tendon should be directed at as near a right angle to the thumb as possible for maximum strength. It should be inserted by two slips, one to the base of the proximal phalanx and the other to the neck of the metacarpal of the thumb. The author commented on the need for osteotomy or webplasty for the correction of adduction contractures. Webplasties were done in few cases. Tendon transfers were found to be adequate in most instances to correct external rotation contractures of the thumb. Stabilization of the interphalangeal joint or base of the carpometacarpal joint of the thumb was used rarely. An intermetacarpal bone block was used in only one case. The use of adhesive strapping as an opponens-tendon splint was described. It was emphasized that the insertions of the transplants must be planned carefully and placed so as to prevent flexor and extensor deformities. These procedures are very successful in children; procrastination only leads to greater deformity.

In the discussion, Dr. Leo Mayer[45] mentioned the good results after various types of operations. He commented on failures caused by changes in the carpometacarpal joint and on the need for the preservation of balanced extension and abduction in the thumb.

Dr. Emanuel B. Kaplan[46] considered this method a simple and effective one. He discussed studies of opposition done on the cadaver; it was noted that muscle stimulation frequently affects more than one muscle, producing a composite effect. He listed the various muscles affecting the thumb joints and stressed the importance of abduction of the thumb in true opposition. He further stressed the importance of abduction of the functional excursion of the motor that is used.

Dr. Thompson, in closing the discussion, commented on the importance of the direction of pull of the tendon from the pulley to the thumb and recommended an operative restoration of thumb opposition at any time after the patient has reached the age of eighteen months.

Extensor Habitus. Dr. William L. White[8] reported his experience with 200 tendon grafts, of which ninety-six exhibited what he called extensor habitus. This was described as an extended position of the finger that was accompanied by varying degrees of fixation of the extended joint. The degree of fixation was thought to depend on alienation or rejection of the flexor muscle. The extended position was observed to be the posture of the hand in sleep. Dr. White outlined his method of splinting and the active and passive exercises followed after tendon-grafting. He also described so-called contralateral suggestion, which he believed was closely akin to hypnosis, as a treatment for so-called extensor habitus, once it had become established.

In discussion, Dr. J. William Littler[47] emphasized the role that the lumbrical muscle may play in producing this extensor abnormality when there is considerable scarring between the lumbrical muscle and the profundus tendon. Under this circumstance the profundus muscle exerts its pull through the lumbrical with very little action on the tendon graft itself. As a result, the profundus pulls the finger into extension by traction on the scarred lumbrical. He emphasized that one must be certain to restore the full amplitude of excursion of the profundus tendon at the time of tendon-grafting, peeling off the lumbrical muscle belly from the profundus tendon back to its true point of origin before the tendon graft is inserted.

A Review of 135 Cases of Tendon Lacerations in the Hand and Wrist. Dr. Claude G. Dupont[48] and Dr. George F. Crikelair[49] presented a study of 110 acute tendon lacerations in the hand and wrist treated by primary repair on the Surgical Service of the Presbyterian Hospital. There were thirty-three lacerations in no man's land, and in thirty there was poor functional return.

43. 535 East 70th Street, New York 21, N. Y.
44. 535 East 70th Street, New York 21, N. Y.
45. 1150 Fifth Avenue, New York 28, N. Y.
46. 1001 Grand Concourse, Bronx 52, N. Y.
47. 16 East 90th Street, New York 28, N. Y.
48. 180 Fort Washington Avenue, New York 32, N. Y.
49. 180 Fort Washington Avenue, New York 32, N. Y.

By contrast, twenty-three tendon grafts for severed tendons in this area gave very satisfactory results, with one exception. In tidy and recent wounds of the hand, a lacerated tendon should always be sutured primarily, except in no man's land. In this area, skin closure alone followed by tendon-grafting after the wound has healed seems to be preferable, except in young patients, in whom primary repair may give a good result. The series presented was of interest because of the very low incidence of crushing injuries; in only five of the 135 injuries cited were there crushed or avulsed wounds. Twenty-four hours is considered the so-called golden period.

In discussion, Dr. Robert D. Larsen [50] limited the golden period to twelve hours. He advocated division of the volar carpal ligament and the use of tourniquets with narrow cuffs that are inflated automatically from a gas cylinder.

Dr. Joseph H. Boyes [51] cited failure in twenty-nine of thirty-three tendon lacerations repaired primarily in no man's land. This result occurred despite ideal conditions of the wound and good surgical technique. He stated further that the problem is not one of technique but of blood supply. Nineteen of twenty-one grafts gave better results where identical technique was used.

Flexor-Tendon Ruptures in the Forearm and Hand. Dr. Joseph H. Boyes [51], Dr. James N. Wilson [52], and Dr. James W. Smith [53], for purposes of this presentation, defined rupture of a flexor tendon as any rupture of a musculotendinous unit between its origin and insertion. Eighty flexor-tendon ruptures, seen in this clinic, were analyzed to define more clearly the incidence, etiology, mechanisms of production, expected sites of rupture, and best form of treatment of this disorder.

The majority of flexor-tendon ruptures occurred in men between thirty and fifty years of age. Tendons of the ring and long fingers were most frequently involved. The ruptures resulted from injuries involving hyperextension, forced flexion, crushing, and laceration. With normal tendons, ruptures occurred at the insertion or musculotendinous junction. Tendons weakened by attrition often ruptured within the tendon substance. Rheumatoid arthritis, tenosynovitis, and bone abnormalities were responsible for the attrition of the tendons in patients with these conditions. There were only three true ruptures of a tendon. The treatment of flexor-tendon rupture was also discussed.

In discussion, Dr. Joseph L. Posch [54] pointed out that neuritis of the median nerve may develop as a result of a tendon graft's being inserted through the carpal tunnel.

Dr. J. William Littler [47] pointed out the value of transillumination of the finger in the detection of whether a flexor tendon has ruptured.

Discussion of Preceding Papers on Tendon Surgery, Question-and-Answer Period. Mr. R. Guy Pulvertaft [5] stated that when he performed a transfer of the tendon of the flexor sublimis muscle he divided the tendon in the palm at the distal palmar crease with the fingers in flexion. By so doing, sufficient length is secured and, in his opinion, the small residual tag of sublimis tendon may prevent a hyperextension deformity at the proximal interphalangeal joint. He considered this maneuver to be of value in children. He stressed Dr. Kaplan's remarks concerning the saddle joint of the carpometacarpal joint of the thumb. He commented briefly on the concept of extensor habitus, and described a patient in whom a good result was obtained by a tendon graft that was performed nine years after injury, using the original muscle motor. He believed that the result obtained would have been better if another motor had been used. He stated that finger ablation is advised for digits with limitation of joint movement and damage of both digital nerves.

In the resulting question period, Mr. Pulvertaft stated that in tendon-grafting he removes the whole theca but leaves three pulleys. In doing tendon repairs distal to the insertion of the flexor sublimis, the whole theca is not removed. Occasionally, pulleys are excised at the time of grafting, and anchorage is secured by sewing down the paratenon. Proximal suture of a graft is done in the heel of the palm, and the distal end is implanted with the aid of reamers into the distal phalanx. The proximal end of a graft is sutured to the profundus rather than to the sublimis tendon, unless the profundus tendon is the smaller of the two. In multiple tendon-grafting procedures three grafts may be done at once, or two in the first and two in a second procedure. He did not advocate primary tendon repair in no man's land. Physical therapy is advised, with supervised active movements, as a rule. Lysis of a tendon, which is done in the failures, has been successful in about 25 per cent of the cases; the whole tendon is exposed, and every adhesion is removed to achieve mobility. Clean sharp dissection is performed without stripping. If cortisone is used, active motion is begun on the first day; about 50 per cent of the patients are helped by cortisone. Mallet-fingers are treated by the method of Dr. Pratt with internal fixation and a plaster cast for two weeks. Rarely, plaster-cast fixation for a period of six weeks is used, resulting in about 40 per cent of poor results and about 20 per cent of improvement with use. Certain tendon grafts were examined at a later operation or at autopsy, and the tendon was always in good condition, but the paratenon was adherent. Mr. Pulvertaft stated that the incidence of causalgia was extremely rare; it may occur in some finger amputations but he has not seen it.

50. 1405 Kales Building, 76 West Adams, Detroit 26, Michigan.
51. 1401 South Hope Street, Los Angeles 15, California.
52. 1401 South Hope Street, Los Angeles 15, California.
53. 232 East 66th Street, New York 21, N. Y.
54. 1405 Kales Building, 76 West Adams, Detroit 26, Michigan.

News Notes

EIGHTH CONGRESS OF THE INTERNATIONAL SOCIETY OF ORTHOPAEDICS AND TRAUMATOLOGY

The Eighth Congress of the International Society of Orthopaedics and Traumatology will be held in New York City, Astor Hotel, September 4 through 9, 1960. All interested doctors and their families are invited to attend whether or not they are members. There is no registration fee for members. The registration fee for non-members is $75. There is a fee of $10 each for all accompanying family members over sixteen years old. Many social events have been planned to entertain visitors during the week of the Congress and special attention will be given to the wives of physicians for whom fashion shows, luncheons, and the like have been arranged. Complete information may be obtained from the Secretary of the Congress, Dr. Lee Ramsay Straub, 535 East 70th Street, New York City.

The preliminary Scientific Program follows:

Monday, September 5, 1960

QUESTION ONE: CONGENITAL DYSPLASIA OF THE HIP
Reporter: Professor Bryan McFarland, Great Britain
Reporter: Dr. Ivar Alvik, Norway
Co-reporter: Dr. Oscar Scaglietti, Italy
Co-reporter: Professor Marino Ortolani, Italy
Co-reporter: Dr. Paul C. Colonna, U.S.A.

10:30 A.M.—Intermission, 30 minutes

Discussors of Question One

1. Professor Boytcho Boytchev, Bulgaria: Congenital Dislocation of the Hip in 1,000 Patients.
2. Dr. Knud Jansen and Dr. E. Hjalmar Larsen, Denmark. The Long-Term Prognosis of Congenital Dislocation of the Hip.
3. Dr. Poul Lutken, Denmark: The Development of the Upper End of the Femur.
4. Dr. Augusto Bonilla and Dr. Guillermo Guerra, Ecuador: Congenital Luxation of the Hip.
5. Dr. Gustav Hauberg, Germany: The Formation of the Roof of the Acetabulum.
6. Professor Hans Mau, Germany: Spontaneous Straightening of the Femoral Neck Following Adduction Osteotomy in Congenital Dysplasia of the Hip.
7. Dr. W. Mohing, Germany: The Development of the Hip Joint After Intertrochanteric Osteotomy.
8. Professor K. Idelberger, Germany: Indications, Technique and Results of the Leveuf's Operation in Congenital Dislocation of the Hip.
9. Professor G. Exner, Germany: The Handling of the Operation and Secondary Treatment of the Dysplastic Hip.
10. Mr. F. C. Dwyer, Great Britain: A Special Treatment for Congenital Dysplasia of the Hip.
11. Mr. E. W. Somerville, Great Britain: Basic Factors to be Considered in the Development of Congenital Dysplasia of the Hip.
12. Dr. Carlo Marino-Zucco, Italy: The Treatment of Congenital Dislocation of the Hip.

Tuesday, September 6, 1960

13. Dr. V. Pietrogrande and Dr. G. Monticelli, Italy: Embryological Dislocation of the Hip.
14. Professor Isaharu Miki, Japan: Special Roentgenogram Studies for Differentiation between Acetabular Dysplasia and Congenital Dislocation.
15. Dr. Saburo Iino, Japan: How Acetabular Dysplasia is Related with the Occurrence of Congenital Dislocation of the Hip.
16. Mr. H. W. Fitzgerald, New Zealand: Etiology and Treatment of Congenital Dysplasia of the Hip.
17. Professor Dr. Wiktor Dega, Poland: The Frequency of Congenital Hip Dysplasia and the Effectiveness of Early Treatment.
18. Professor Dr. Al Radulescu, Rumania: Some Considerations about the Congenital Dislocation of the Hip, Based on Personal Experience.
19. Dr. Sophus von Rosen, Sweden: Diagnosis and Treatment of Congenital Dislocation of the Hip Joints in New-Borns.
20. Professor José L. Bado, Uruguay: Etiology and Treatment of Congenital Dysplasia of the Hip.
21. Professor Dr. Bodgan Brecelj, Yugoslavia: Radiographic Observations in the Course of Postnatal Spontaneous Evolution of Dysplastic Hips.
22. Professor Syotaro Mizuno, Japan: Difficulties in Surgery of the Congenital Hip Dislocation with a Report on a Central Arthroplasty and a Horizontal Osteotomy of the Pelvis.

23. Dr. Robert B. Salter, Canada: Innominate Osteotomy in Congenital Dislocation of the Hip.
24. Dr. Paul A. Pemberton, U.S.A.: Rotation of the Acetabular Roof for Treatment of Congenital Dysplasia of the Hip.

10:30 A.M.—Intermission, 30 minutes

25. Dr. William S. Smith, U.S.A.: Experimental Aspects of Congenital Dislocation and Congenital Dysplasia of the Hip.
26. Dr. Joseph E. Milgram, U.S.A.: Gradual Reduction in the Congenital Dislocation of the Hip in Infancy.
27. Dr. Beckett Howorth, U.S.A.: Basic Factors in the Etiology of Congenital Dysplasia of the Hip.
28. Dr. H. R. McCarroll, U.S.A.: Is Congenital Dysplasia of the Hip a Forerunner of Congenital Dislocation?

11:45 A.M.: QUESTION TWO: THE STUDY OF OSTEOGENESIS WITH ITS RELATION TO DELAYED UNION AND PSEUDARTHROSIS

Reporters: Dr. Harold B. Boyd, U.S.A.
Dr. J. Judet, France
Dr. R. Judet, France
Dr. Robert D. Ray, U.S.A.

Wednesday, September 7, 1960

Discussors of Question Two

1. Mr. J. Francis Silva, Ceylon: Pseudarthrosis of the Long Bones.
2. Dr. Alberto Inclan, Cuba: Prevention and Treatment of Pseudarthrosis, Especially in Fractures of the Femoral Neck.
3. Dr. Poul Lutken, Denmark: Osteogenesis and the Treatment of Delayed Consolidation and Pseudarthrosis of the Long Bones.
4. Dr. Merle d'Aubigné, France: Treatment of Non-union in Long Bones.
5. Dr. J. D. Ramadier, France: The Treatment of Pseudarthrosis of the Leg by Inter-Tibio-fibular Graft.
6. Dr. Eduard Guntz, Germany: The Use of CIALIT-Preserved Bone in Nearly 800 Operations.
7. Professor K. Idelberger, Germany: Experiences with the Preservation of Bone in Palacos.
8. Professor M. Küntscher, Germany: The Treatment of Pseudarthrosis with Intramedullary Nailing.
9. Dr. Max Lange, Germany: The Use of Homoplastic and Autoplastic Bone Transplants in over 1,500 Cases.
10. Mr. R. G. Taylor, Great Britain: The Use of Bone Grafts in Malposition and Non-union of Fractures of Shafts of Long Bones.
11. Mr. E. A. Nicholl, Great Britain: Non-union of Fractures of Long Bones.
12. Mr. J. Trueta, Great Britain: Recent Views on Osteogenesis: An Experimental Study.

10:30 A.M.—Intermission, 30 minutes

13. Dr. M. Boni and Dr. V. Pietrogrande, Italy: Recovering Osteogenesis in the Pathological Fractures.
14. Dr. G. Monticelli and Dr. M. Boni, Italy: On a Particular Feature of the Pathology of Bone Callus: The Delayed Pseudarthrosis.
15. Dr. M. Paltrinieri, Italy: A New Approach in the Treatment of Delayed Union and Pseudarthrosis of the Tibia.
16. Dr. Clement C. Baciu, Rumania: The Effects of Beta-indolilacetic Acid (a Hormone of Growth of the Plants) on the Callus Formation in Long Bones.
17. Professor Dr. Jean Jiano, Rumania: Reattachment, Grafts, and Segmental Resections and the Restorative Surgery of the Extremities.

12:00 P.M. to 1:00 P.M.—General Assembly

Thursday, September 8, 1960

18. Dr. D. Pintilie and Dr. M. Fahrer, Rumania: Osteogenesis by Urinary Bladder Mucous Membrane in the Treatment of Pseudarthrosis of Long Bones.
19. Dr. Maurice E. Müller, Switzerland: Biomechanical Principles in Osteosynthesis of Pseudarthrosis.
20. Dr. G. W. N. Eggers, U.S.A.: The Contact-Compression Factor in Osteogenesis.
21. Dr. Edward L. Compere, U.S.A.: Promotion of Osteogenesis and Prevention of Delayed Union and Pseudarthroses of Long Bones.

9:15 A. M.—SYMPOSIUM

TEACHING AND TRAINING IN ORTHOPAEDIC SURGERY AND TRAUMATOLOGY AND THE ORGANIZATION OF HOSPITAL SERVICES

Moderator: Sir Harry Platt, Great Britain
Introduction: Dr. F. E. Godoy-Moreira, Brazil

Reporters: Dr. Merle d'Aubigné, France
Professor Alfred Witt, Germany
Dr. R. Zanoli, Italy
Dr. H. A. Sofield, U.S.A.

10:45 A.M.—Intermission, 30 minutes

Discussors of Symposium

1. Mr. H. W. Fitzgerald, New Zealand: The Orthopaedic and Fracture Service at the Dunedin Hospital and Otago Medical School.
2. Dr. Alan DeF. Smith, U.S.A.: Teaching and Training at the New York Orthopaedic Hospital over a Period of 37 Years.

12:00 P.M.—INDIVIDUAL COMMUNICATIONS

1. Dr. José Valls, Argentina: Treatment of Chronic Osteomyelitis of the Limbs.
2. Dr. Herbert Gardemin, Germany: Early Primary Chronic Osteomyelitis.
3. Mr. Denys Wainwright, Great Britain: Septic Arthritis of the Hip in Infants.
4. Professor José L. Bado, Uruguay: Injuries to the Upper Extremity by Rotation.
5. Dr. J. A. Nova Monteiro, Brazil: New Concepts on the Monteggia Lesion—Its Application on Treatment.

Friday, September 9, 1960

6. Dr. R. Soeur, Belgium: A New Technique of Surgical Immobilization of the Bone.
7. Dr. D. Pintilie, Rumania: Apparatus for Obtaining Bone Union of the Femoral Neck.
8. Professor Dr. Jean Jiano and Dr. Octav Vladutziu, Rumania: An Annular Type of Femoral Callus.
9. Professor Domingos Define, Brazil: Implantation of the Fibula in Diaphyseal Bone Defects of the Tibia.
10. Dr. Goran C. H. Bauer, Sweden: Epidemiology of Fracture in Old Persons.
11. Dr. Waldemar Rosa dos Santos, Brazil: High Intertrochanteric Osteotomy and Fixed Bone Graft for Non-Union of Fractures of the Neck of the Femur.
12. Dr. René Charry, France: The Resection Angulation of the Hip in Surgery.
13. Dr. Maurice E. Müller, Switzerland: Adduction Osteotomies in the Treatment of Coxarthrosis.
14. Dr. A. Glauber, Hungary: Hyperextension Subtrochanteric Osteotomy.

10:30 A.M.—Intermission, 30 minutes

15. Professor M. Hackenbroch, Germany: The Treatment of the Paralytic Hip Joint.
16. Dr. Augusto S. Besa, Philippines: The Use of the Iliac Crest as a Full-Thickness Graft in Spine Fusion (A New Method).
17. Dr. Walter P. Blount, U.S.A.: Congenital Scoliosis.
18. Mr. R. W. Butler, Great Britain: The Significance of Osteochondrosis Vertebralis Juvenilis in Spinal Pathology.
19. Dr. F. Gaynor Evans, U.S.A.: Effects of Controlled Accelerations on Stress-Strain Phenomena in the Intact Vertebral Column.
20. Professor Boris Conforty, Bulgaria: Elongating Arthrodesis of the Knee Joint.
21. Dr. Roger Gariepy, Canada: Surgical Treatment of the Arthritic Knee with Emphasis on the Correction of Flexion Deformities in Chronic Rheumatoid Conditions.
22. Dr. Lenox D. Baker, U.S.A.: Indications for Early Surgery in Cerebral Palsy.
23. Mr. F. C. Dwyer, Great Britain: Osteotomy of the Os Calcis in the Treatment of Grossly Everted Feet with Particular Reference to Cerebral Palsy.
24. Dr. R. deMarneffe and Dr. G. Hendrix, Belgium: Congenital Talipes Equinovarus, a Concept of Treatment and Surgical Procedure.
25. Mr. D. L. Savill, Great Britain: Repair of Rupture of the Tendo-achillis, with Particular Reference to Old Injuries.

Friday Afternoon Session

26. Dr. Joseph Woodward, U.S.A.: Muscle Origin Release Operation for Congenital Elevation of the Scapula.
27. Dr. Henrique DeGoes, Brazil: The Radiohumeral "Meniscus" and Its Relation with Tennis Elbow.
28. Professor Aldo Arienti, Italy: Arteriography in the Diagnosis of Bone Tumors.
29. Dr. Rafael Esteve, Spain: Study of Peripheral Blood Circulation in Patients with Poliomyelitis, Measured by Testing the Vasodilatation Reflex in Its Relation to the Severity of Motor Paralysis.
30. Dr. P. K. Duraiswami, India: Experimental Induction of Congenital Defects.
31. Dr. Miroslav Delic, Yugoslavia: The Implantation of the Epiphysis Plate Between the Fracture Fragments of a Rabbit's Long Bone.
32. Professor G. Exner, Germany: Observations of an Extensive Periosteal Change as a Result of a Transsection Paralysis with a Myelodysplasia.
33. Dr. Philip Salib, Egypt: Orthopaedic and Traumatic Skeletal Lesions in Ancient Egyptians.

34. Dr. W. Taillard and Dr. H. Kaufmann, Switzerland: The Abnormal Pelvic Development in Mongolism.

4:30 P.M.—Closing Ceremony

Papers to be Read by Title

1. Professor José L. Bado, Uruguay: Disturbances in Embryonic Development of the Muscles and Their Responsibilities in the Physiopathology of Some Congenital Deformities.
2. Dr. Lenox D. Baker, U.S.A.: Hip Pathology in the Cerebral Palsy Patient.
3. Dr. Edgar M. Bick, U.S.A.: Fracture Healing in the Aged.
4. Colonel Ernst Dehne, U.S.A.: Primary and Delayed Healing of Intra-articular Fractures.
5. Dr. George O. Eaton, U.S.A.: Delayed Union in Femoral-Neck Fractures.
6. Dr. Edward T. Evans, U.S.A.: The Prophylactic Use of the Frejka Splints Based on Clinical Suspicion of Hip Dysplasia.
7. Dr. Julian E. Jacobs, U.S.A.: Metatarsus Varus and Hip Dysplasia.
8. Dr. Knud Jansen, Denmark: Pedicle Bone Graft in Hip Arthrodesis.
9. Dr. J. H. Kite, U.S.A.: Familial Osteolysis.
10. Dr. K. Lindemann, Germany: The Use of a Pneumatic Prosthesis with Pectoral Cineoplasty in the Patient without Hands.
11. Dr. Earl D. McBride, U.S.A.: The Shackled Socket Acetabular Replacement Prosthesis.
12. Dr. Leo Mayer, U.S.A.: Paralytic Pelvic Obliquity.
13. Dr. Henry Milch, U.S.A.: Isolated Fractures of the Humeral Condyles.
14. Dr. Maurice E. Müller, Switzerland: The X-ray Diagnosis of Mechanical Conditions of the Hip.
15. Dr. J. A. Nova Monteiro, Brazil: A New Technique for the Treatment of Konig's Lesion of the Knee Joint.
16. Dr. R. S. Reich, U.S.A.: The Treatment of Disabilities Following Dysplasias of the Hip in the Adult.
17. Mr. D. Wainwright, Great Britain: Slipped Upper Femoral Epiphysis-Subtrochanteric Abduction Osteotomy in the Treatment of Irreducible Displacement.

Audiovisual Program

1. Dr. Aldo Arienti, Italy: The Treatment of Fractures of the Neck of the Femur.
2. Dr. A. S. Besa, Philippines: Use of Iliac Crest as Full-Thickness Graft in Spine Fusion.
3. Dr. J. Böhler, Austria: Primary Restorative Surgery in Severe Hand Injuries.
4. Dr. Joseph E. Brown, U.S.A.: Cutis Arthroplasty of Joints.
5. Dr. Mark Coventry and Dr. David C. Dahlin, U.S.A.: The Diagnosis and Treatment of Tumors of Bone.
6. Dr. R. deMarneffe, Belgium: Congenital Talipes Equinovarus.
7. Dr. James A. Dickson, U.S.A.: Cancellous Bone Grafts in Femoral-Neck Fractures.
8. Dr. Mac Fellander, Sweden: External Skeletal Transfixation.
9. Dr. Paul Goldhaber, U.S.A.: Experimental Bone Resorption in Tissue Culture.
10. Dr. P. R. Harrington, U.S.A.: Management of Scoliosis with Metallic Struts.
11. Dr. M. B. Howorth, U.S.A.: Technique of Hibbs Spine Fusion.
12. Dr. Saburo Iino, Japan: Vector-Analyzing Basography.
13. Dr. M. Küntscher, Germany: Intramedullary Nailing.
14. Dr. Max Lange, Germany: The Treatment of Antetorsion of Congenital Luxation with Derotational Femoral Osteotomy.
15. Dr. D. K. Lindemann, Germany: Application of Pneumatic Prosthesis with Pectoral Cineplasty.
16. Dr. Paul Magnuson, U.S.A.: Hip Arthroplasties.
17. Dr. C. Marino-Zucco, Italy: Operative Treatment of Congenital Dislocation of the Hip.
18. Dr. Leo Mayer, U.S.A.: Fixed Paralytic Pelvic Obliquity.
19. Dr. Roberto Morales-Ryes, Mexico: Elbow Prosthesis.
20. Dr. Maurice E. Müller, Switzerland: Internal Fixation of Tibial Fractures by Compression Screws.
21. Mr. E. A. Nicholl, Great Britain: Non-union of Fractures of Long Bones.
22. Dr. M. Ortolani, Italy: Diagnosis, Prophylaxis, and Treatment of Congenital Hip Dislocation.
23. Mr. Geoffrey Osborne, Great Britiain: History, Mechanics, and Practical Application of the Thomas Splint.
24. Dr. Garrett Pipkin, U.S.A.: Tardy Spina Bifida Occulta Syndrome.
25. Dr. Robert D. Ray, U.S.A.: Tissue Culture Studies of Bone.
26. Dr. H. Reitz, South Africa: A New Operation for Repair of Ruptured Anterior Cruciate Ligament.
27. Dr. G. Rose and Dr. T. O. Shindler, U.S.A.: Osteoblasts in Tissue Culture.
28. Dr. O. Scaglietti, Italy: Congenital Dislocation of the Hip.
29. Mr. E. Shephard, Great Britain: Tarsal Movements.
30. Dr. T. C. Thompson, U.S.A.: Quadricepsplasty.
31. Dr. Carl Walter, U.S.A.: Hospital Sepsis: A Communicable Disease.

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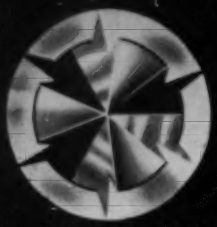

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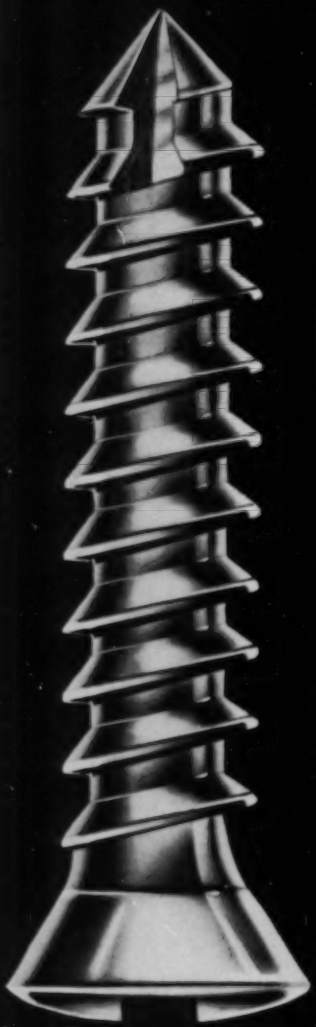

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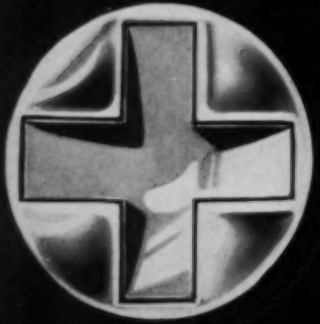

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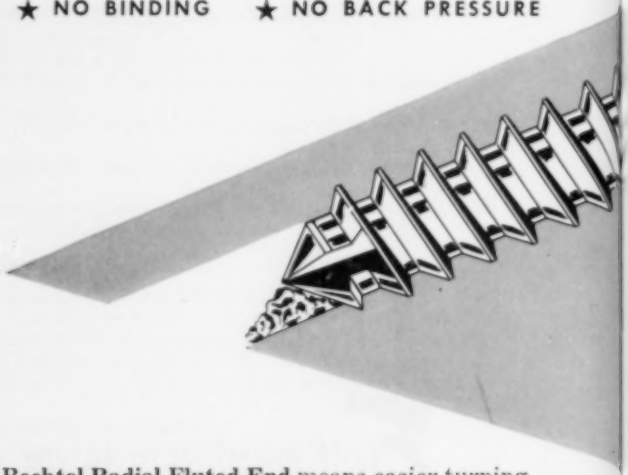

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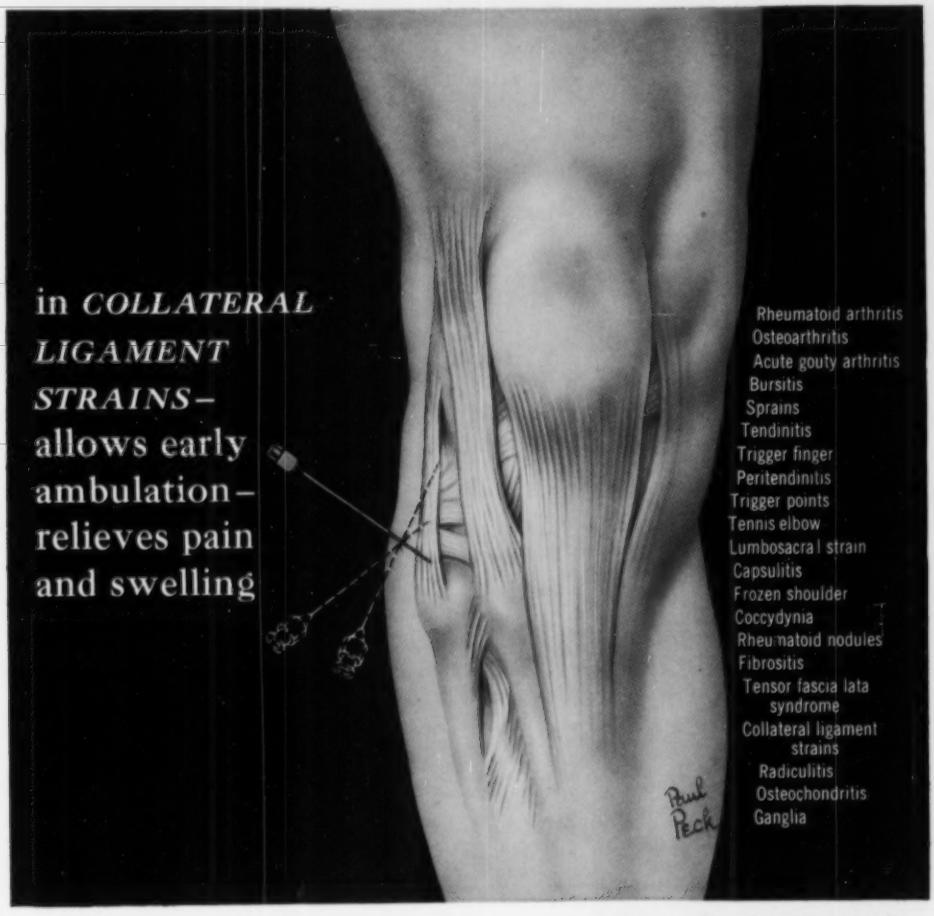

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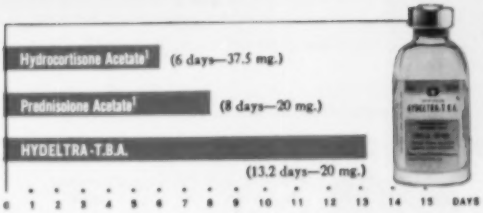
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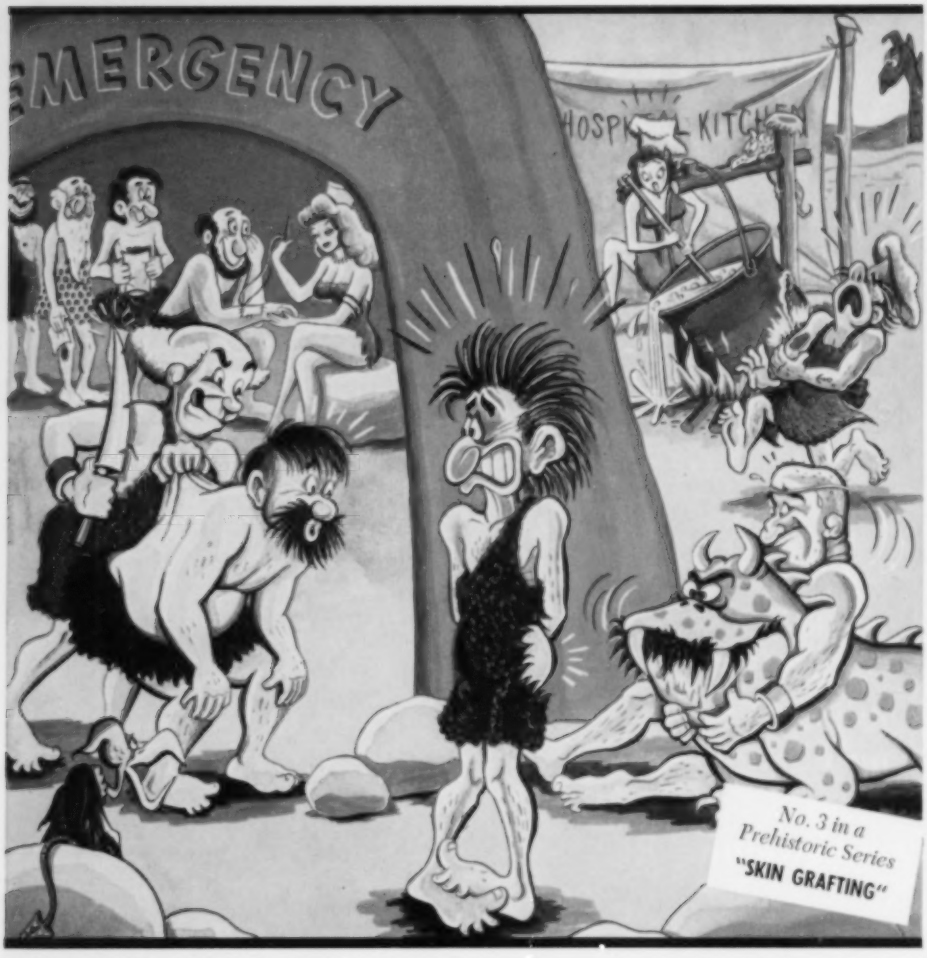

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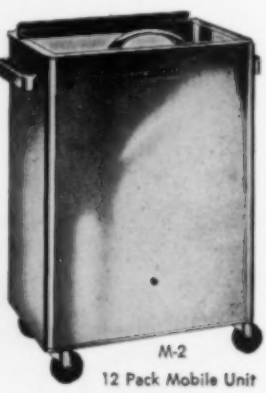

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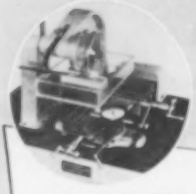

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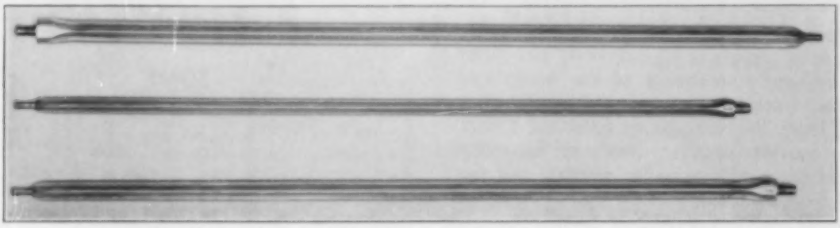

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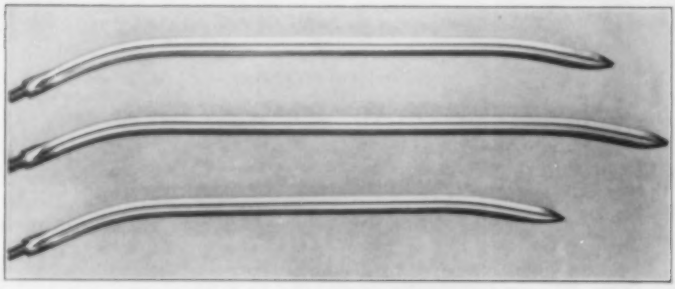

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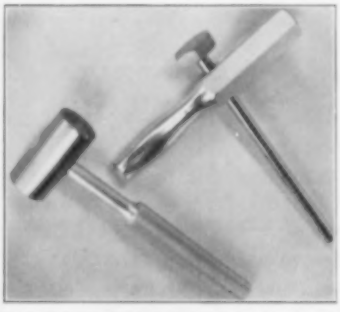

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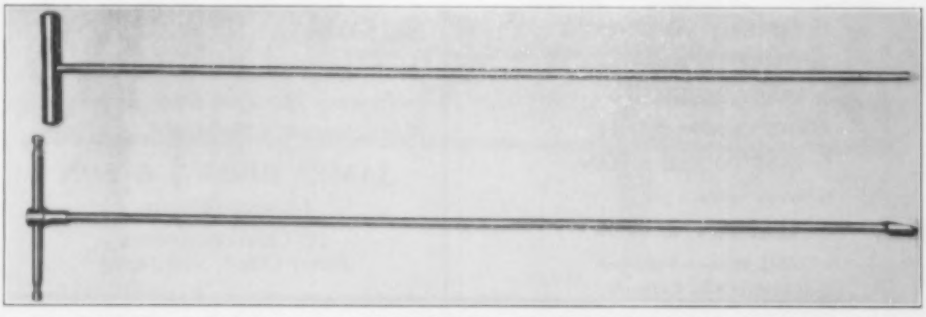

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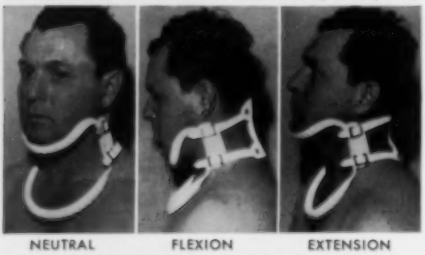

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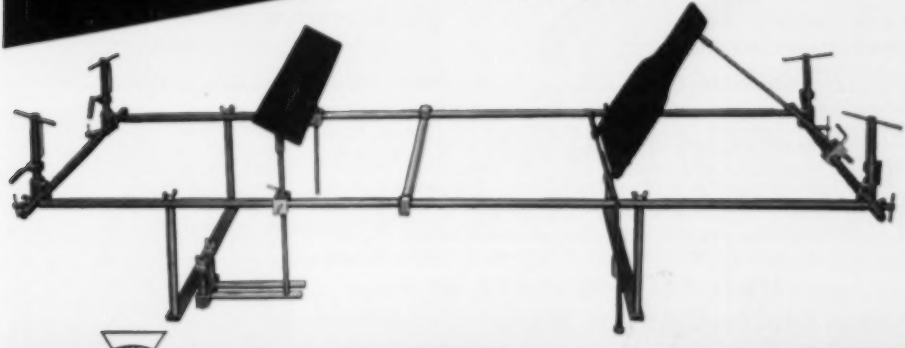

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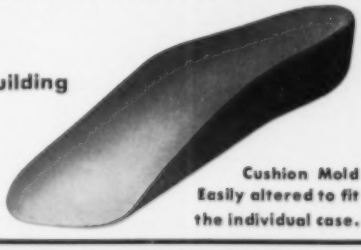

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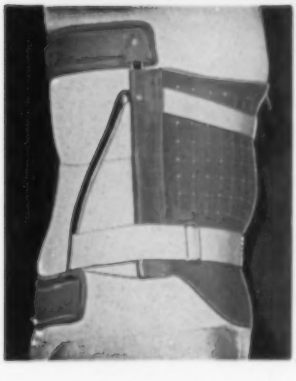

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